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CONTENTS

THE INSECT FAUNA OF THE WASTE AREAS OF TILBURY DOCK

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AT the request of the Ministry of Agriculture and Fisheries I undertook during the summer of 1938 a partial survey of the insect fauna of the Tilbury Dock area. By kind permission of the Trustees of the British Museum (Natural History) I was given the services of Mr. T. G. Howarth as assistant.

The main object of this survey was connected with the occurrence of the Colorado Beetle at Tilbury the previous year. It was thought possible that it might be found on the *Solanum dulcamara* which is a known food-plant of the larva and which occurs all over the waste ground in the dock area, but although this plant was thoroughly examined on each visit, no trace of the beetle or its larvae could be found.

The area surveyed comprises the whole of the Port of London Authority land within the Customs fence, a portion outside the fence to the north-west and a triangular piece between the Main Dock, Tidal Basin and the river, known locally as the Coaling Jetty (several hundred acres in all). The terrain is bordered on the south and west by the River Thames, on the east by the London, Midland and Scottish Railway, and on the north by the Grays Thurrock marsh.

In early days it must have been an extensive area of marshland, intersected by creeks and reedy ditches, of which very little trace now remains. The area not actually occupied by the docks and jetties has for years been used as a dump heap for rubbish, and when the docks were made some of the excavated soil was also spread there.

An embanked concrete road runs through the centre of the ground from Tilbury Dock Station right round to the Main Dock, and for part of the way it is bordered by the Dock railways.

Except for a few pools and hollows, the ground level is now considerably higher than formerly.

Almost the whole area has become colonised by waste-land plants, thistles being in the majority, though in places, hemlock grows in great masses. *Solanum dulcamara* is scattered over the whole of the ground, but some of it appeared to have been cut out within the last year or so.

With the exception of the pieces adjoining the railway lines, the embankment of the road, and various portions near buildings in the dock areas, very little mowing seems to be done, only so much as is necessary to prevent damage by grass fires and to keep the railway tracks clear.

For the purposes of the survey the ground was divided into four sections,

viz. : the north and south sides of the concrete road, the Coaling Jetty piece and the allotment piece near Manor Way Gate.

The next consideration was the flora.

The north side consists of alternate hollows and raised ground. Reed grows in the hollows in some quantity, while on the higher portions thistles, teasels, hemlock and some *Lepidium draba* grow but rather more scattered than on the south side. At about the centre the ground falls away into a grassy hollow with a football field on the roadside and an area of blackthorn and hawthorn on the northern boundary. Farther west towards the river the ground rises again, where there is a mass of thistle, hemlock, ragwort and some teasel. *Solanum* is scattered over most of the higher portions.

On the south side there was a belt of *Carduus tenuiflorus* on the road bank. This gave way farther in to large masses of *Carduus lanceolatus*, hemlock and *Lepidium.* The ground falls towards a hollow in the middle where there are two reed-fringed pools. A raised cinder pathway divides the hollow. Around the pools is a grassy area dotted with small hawthorn and blackthorn bushes.

On the western side of the grassy area is a small tidal creek with some *Aster tripolium* growing in the north-west corner. The ground rises sharply beyond the creek, the western bank of which was covered with large masses of *Solanum dulcamara.* Farther west towards the lock was a very thick mass of hemlock, thistles and convolvulus. Beyond the lock was a triangular piece of ground, the flora of which was more varied and comprised *Helminthia echioides, Sinapis nigra* and *S. incana, Picris hieracioides, Convolvulus sepium, Rapistrum linneanum* var. *glabra, Lepidium draba, Carduus lanceolatus* and *C. arvensis, Artemisia vulgaris,* and *A. absinthium, Centranthus ruber, Lactuca virosa* (2 forms), *Clematis vitalba,* and some hawthorn, sallow, bramble, willow herbs and ragwort. Some *Solanum* grew on this piece.

The Coaling Jetty piece contained the richest flora of all the sections. Parts of it were open and grassy with rather a dwarfed plant-growth. Dotted about were bushes of elder, birch, hawthorn, blackthorn, sallow, sycamore, and clumps of bramble and *Clematis vitalba.* *Solanum dulcamara* grew more or less all over this section. There were three fair-sized patches of reed. Among the other plants observed were *Sinapis nigra* and *S. incana, Sisymbrium altissimum* (= *pannonicum*), *S. orientale* (= *columnae*), *Rapistrum linneanum* var. *glabrum, Helminthia echioides, Picris hieracioides, Lactuca virosa* (2 forms), *Carduus lanceolatus* and *C. arvensis, Centranthus ruber, Senecio viscosus, Vicia* species, burdock, hemlock, ragwort, mayweed, and teasel. The allotment piece was also fairly rich in plant life, open and grassy at the Manor Way Gate end with a few seedling birches, sallows, clumps of bramble and a strip of reed in the middle. At the northern end were a number of allotments.

Many of the bushes of *Salix caprea* to the north of the concrete road near the railway lines were infested with a gall which has a different appearance from that on *Salix alba.* Dr. A. M. Massee has identified it as *Eriophyes triradiatus (typicus)* Nalepa.

On 25 May I went to Tilbury, where I was met by Messrs. Buckhurst, Strang and Thomas, who pointed out to me the area to be examined on either side of the concrete road. Near Manor Way Gate there are some allotments, which were carefully examined on each subsequent visit, but without result.

On 13 and 14 June the north and south sections and the allotment piece were thoroughly explored. About 20 species of Lepidoptera and Coleoptera were noticed. *Plutella maculipennis* was abundant among *Lepidium.* *Myelois cribrella* and *Loxostege verticalis* were common among thistles. The blackthorn

and hawthorn bushes on the western side of the north-west section were almost defoliated by larvae of *Hyponomeuta padella*, which were in immense numbers. They were, however, heavily parasitised. Cuckoos in some numbers were frequenting the bushes. It is possible that they were feeding on the larvae.

From 17 to 19 June all sections were visited. With Mr. Howarth's help the sections north and south of the road were also worked at night. Both sugar and light were tried. Last year's teasel stems, cut and stuck up every few yards, for want of anything better to put the sugar on, proved quite attractive. About 60 species of Lepidoptera, including 1 *Nomophila noctuella*, were noticed.

On 18 June while visiting the allotment piece at about 6 p.m. 3 specimens of *Trichius abdominalis* Men. were found. Two of them were in Convolvulus blossoms and one in a bramble blossom.

From 8 to 10 July all sections were again visited. It was decided to inspect the Coaling Jetty section, which is situated outside the Customs fence and adjoins the river. Incidentally a large number of steamers put in there to coal; therefore it appeared to be a likely place for any imported species to land. We worked this piece on both nights with sugar and light, using teasel heads and straw bottle-cases and drift wood collected from the fore-shore for the sugar. A large number of species of both macro- and micro-lepidoptera were observed, but no alien species. The weather conditions on 9 July were against us. It was difficult to find any shelter from the wind, consequently the bag was a very small one.

All sections were visited from 29 to 31 July. The Coaling Jetty piece was worked at night on 29 July. This was our best night, a very large number of species being observed. One specimen of *Loxostege palealis* was taken. On the night of 30 July we worked the south side of the road, but weather conditions were bad, consequently only a few of the more robust macrolepidoptera were seen.

All sections were visited from 27 to 29 August. In addition we explored the ground outside the Customs fence to the north-west, walking from Tilbury Dock Station along the Dock Railway to the North End Gate and then turning west towards the river. At the river-side of this section there is quite a big hill of old dumped refuse. This has now become covered with waste-land plants.

Larvae of *Loxostege palealis* were abundant on *Daucus carota* growing on the grassy portions just before we reached the hill. We decided to work the Coaling Jetty piece on the night of 27 August, but on arrival there found that an extensive grass fire had set light to the old coal refuse dumped there some years ago. The fire was burning underground and had already destroyed most of the plant growth on the western half of this section. As it was then too late to get to any of the other sections, we were forced to confine ourselves to a small corner at the south-eastern end, which was away from the smoke, but rain coming on rather heavily put an end to collecting. 1 *Nomophila noctuella* was taken on this section.

The section north of the concrete road was worked on the night of 28 August. Numbers of common species were noted but *Amathes xanthographa* was the principal visitor to the sugar and *Luperina testacea* to the light. It became cool and foggy about midnight, so we had to leave.

There was nothing very striking among the Rhopalocera. Several *Argynnis cydippe* were seen. *Vanessa cardui*, though observed in some numbers in May, was scarce in August and no larvae or pupae were found. One fresh *Colias croceus* was found on 29 August. The Essex Skipper *Adopoea lineola* was abundant on the grassy portions.

Among the Heterocera, it was interesting to find that many of the species formerly associated with the Thames marshland such as *Nonagria geminipuncta, N. dissoluta* and ab. *arundineta, Rhizedra lutosa, Arenostola phragmitidis, Leucania obsoleta, L. straminea* and *Chilodes maritima*, still occurred among the reeds at Tilbury. The typical black *N. dissoluta* seems to be far more plentiful than the ab. *arundineta* in this locality, about 10 *dissoluta* to 1 ab. *arundineta* were bred from collected larvae. *Triphaena pronuba* was in immense numbers and very variable. *T. interjecta* was also plentiful, flying swiftly round the bushes at dusk and as usual difficult to catch. *Procus bicoloria* swarmed at dusk and afterwards at sugar. Two specimens of *Apamea oblonga* came to sugar near the sea-wall.

We quite expected to see *Laphygma exigua* but it did not appear.

The most interesting GEOMETRIDAE were *Hemistola chrysoprasaria, Horisme vitalbata* and *H. tersata*, no doubt living amongst the *Clematis vitalba, Scopula immutata* in the marshy places and the black ab. *rebeli* of *Cleora rhomboidaria*.

The PYRALIDINAE were quite interesting. A rather curious-looking *Ephestia elutella, Homoeosoma sinuella* which I hardly expected and *H. binaevella. Myelois cribrella* was very common; the larvae must control the spear thistle to some extent. In August there was hardly a flower-head without a larva. *Eurhodope advenella* and *E. suavella* turned up at light. A few *Nomophila noctuella* were seen and larvae of *Loxostege palealis* were common in heads of *Daucus. L. verticalis* was abundant. About 58 species of microlepidoptera were noticed. Those nice species : *Polychrosis fuligana, Eucosma conterminana* among the *Lactuca* and *E. pupillana*, which I had previously only seen from Portland among the *Artemisia absinthium*. Some fine *Eucosma foenella* were bred from larvae found in the roots of *Artemisia vulgaris. Phthorimaea costella* larvae were mining the terminal shoots of *Solanum* and were parasitised by a species of *Rhysipolis* (BRACONIDAE). *Plutella maculipennis* was abundant among *Lepidium draba :* the larvae were much parasitised by *Angitia fenestralis* (Grav.) (ICHNEUMONIDAE).

We found Coleoptera rather scarce, possibly owing to the drought; sweeping produced very little except the *Solanum* flea beetles *Psylliodes dulcamarae* and *P. affinis ;* shaking heaps of mown grass and rubbish on the banks was also unproductive; it was too dry, and rather too full of thistle stems. The most interesting capture was three specimens of the pretty chafer *Trichius abdominalis* on 18 June. It was not possible to do much with other orders but a few Hymenoptera, Hemiptera–Heteroptera, and Hemiptera–Homoptera and Diptera were noted.

LIST OF INSECTS OBSERVED.

Rhopalocera.

SATYRIDAE.

Maniola jurtina (L.).   *Coenonympha pamphilus* (L.).

NYMPHALIDAE.

Argynnis cydippe (L.).   *Aglais urticae* (L.) and larvae.
Vanessa atalanta (L.).   *Nymphalis io* (L.).
V. cardui (L.).

LYCAENIDAE.

Polyommatus icarus (Rott.).   *Lycaena phlaeas* (L.).

PIERIDAE.

Pieris brassicae (L.).   *P. napi* (L.).
P. rapae (L.).   *Colias croceus* (Fourcroy).

HESPERIIDAE.

Adopoea lineola Ochs.   Common.   *Ochlodes venata* B. & G.

Heterocera.

ARCTIIDAE.

Spilosoma lubricipeda (L.). (White   *Arctia caja* (L.).
  ermine).   *A. villica* (L.).
S. lutea (Hufn.).   (Buff ermine).   *Callimorpha jacobaeae* (L.).

NOTODONTIDAE.

Cerura vinula (L.) (and larvae).   *Malacosoma neustria* (L.) (and larvae).
Phalera bucephala (L.).

LASIOCAMPIDAE.

Philudoria potatoria (L.) (and larvae).

AGROTIDAE.

Cryphia perla (Fab.).   *H. trifolii* (Rott.) and larvae.
Agrotis segetum Schiff.   *Ceramica pisi* (L.) and larvae.
A. radius Haw.   *Tholera popularis* (Fab.).
A. exclamationis (L.).   *Luperina testacea* (Hübn.).
A. ipsilon (Rott.).   *Thalpophila matura* (Hufn.).
Euxoa nigricans (L.).   *Apamea oblonga* (Haw.).
Amathes c. nigrum (L.).   *A. obscura* (Haw.).
A. xanthographa (Fab.).   *A. basilinea* (Schiff.).
Diarsia rubi (View.).   *A. secalis* (L.).
Ochropleura plecta (L.).   *A. lithoxylea* (Fab.).
Axylia putris (L.).   *A. monoglypha* (Hübn.).
Triphaena comes (Hübn.).   *Procus strigilis* (Clerck).
T. pronuba (L.).   *P. latruncula* (Schiff.).
T. ianthina (Esp.).   *P. fasciuncula* (Haw.).
T. interjecta (Hübn.).   *P. literosa* (Haw.).
Mamestra brassicae (L.).   *P. bicoloria* (Vill.).
Melanchra persicariae (L.).   *Euplexia lucipara* (L.).
Diataraxia oleracea (L.) and larvae. *Phlogophora meticulosa* (L.).
Hadena suasa (Schiff.).   *Hydroecia micacea* (Esp.).

Gortyna flavago (Schiff.).
Nonagria geminipuncta (Haw.) (larvae).
N. dissoluta Tr. (larvae).
N. d. ab. *arundineta* Schmidt. (larvae).
Chilodes maritima (Tausch.).
Rhizedra lutosa (Hübn.) (larvae).
Arenostola phragmitidis (Hübn.) (and larvae).
Leucania pallens (L.).
L. impura (Hübn.).
L. straminea Tr. (and larvae).
L. obsoleta (Hübn.).

L. lithargyria (Esp.).
L. conigera (Fab.).
Meristis trigrammica (Hufn.).
Caradrina morpheus (Hufn.).
C. alsines (Brahm).
C. quadripunctata (Fab.).
Rusina umbratica (Goeze).
Amphipyra tragopoginis (L.).
Plusia chrysitis (L.).
P. gamma (L.).
Euclidimera mi (Clerck) (and larvae).
Hypena proboscidalis (L.).
Zanclognatha tarsipennalis (Tr.).

GEOMETRIDAE.

Hemistola chrysoprasaria (Esp.).
Sterrha seriata (Schr.).
S. fuscovenosa (Gze.).
S. aversata (L.).
S. biselata (Hufn.).
S. dimidiata (Hufn.).
Scopula immutata (L.).
Ortholitha chenopodiata (L.).
Anaitis plagiata (L.).
Xanthorhöe spadicearia (Schiff.).
X. montanata (Schiff.).
X. fluctuata (L.).
Epirrhöe alternata (Mull.).
Euphyia bilineata (L.).
Eupithecia haworthiata Dbldy.

E. linariata (Fab.).
E. centaureata (Schiff.).
E. succenturiata (L.).
Horisme vitalbata Schiff.).
H. tersata (Schiff.).
Abraxas grossulariata (L.).
Cabera pusaria (L.).
Selenia bilunaria (Esp.) 2 gen. *illunaria* (Esp.).
Crocallis elinguaria (L.).
Opisthograptis luteolata (L.).
Biston betularia (L.) (and larva).
Cleora rhomboidaria (Schiff.).
C. r. ab. *rebeli* (Aign.).
Aspilates ochrearia (Rossi.).

ZYGAENIDAE.

Zygaena filipendulae (L.) (1 cocoon).

Pyralidina.

PHYCITIDAE.

Ephestia elutella (Hübn.).
Homoeosoma sinuella (Fab.).
H. binaevella (Hübn.).

Myelois cribrella (Hübn.) (very common and larvae).
Eurhodope advenella (Zinck.).
E. suavella (Zinck.).

CRAMBIDAE.

Crambus pascuellus (L.)
C. pratellus (L.).
C. culmellus (L.).
C. hortuellus (Hübn.).

C. perlellus (Scop.).
C. geniculeus (Haw.).
C. tristellus (Fab.).
Chilo phragmitellus (Hübn.).

PYRAUSTIDAE.

Phlyctaenia prunalis (Schiff.).
P. sambucalis (Schiff.).
Nomophila noctuella (Schiff.)
Loxostege verticalis (L.) (common).

L. palealis (Schiff.) (larvae common).
Scoparia cembrae Haw.
Mesographe forficalis (L.).
Endotricha flammealis (Schiff.).

Microlepidoptera.

PTEROPHORIDAE.

Platyptilia gonodactyla Schiff.
P. pallidactyla Haw.

Alucita pentadactyla L.
Pterophorus monodactyla L.

PHALONIIDAE.

Phalonia tesserana Treits.
P. roseana L.
P. atricapitana Steph.

P. pallidana Zell.
P. hybridella Hübn.
Euxanthis hamana L.

TORTRICIDAE.

Pandemis ribeana Hübn.
Tortrix paleana Hübn.
T. unifasciana Dup.

Cnephasia vigaureana Treits.
Peronea asperana Hübn.
P. variegana Schiff. ab. *fuscana* Sheldon.

EUCOSMIDAE.

Spilonota ocellana Fab.
Notocelia uddmanniana L.
Eucosma nigromaculana Haw.
E. citrana Hübn.
E. pupillana Clerck.
E. conterminana H.-S.
E. cana Haw.
E. foenella L.
E. brunnichiana Froel.
E. tripunctana Fab.

Polychrosis fuligana Haw.
Argyroploce pruniana Hübn.
A. lacunana Dup.
A. urticana Hübn.
Hemimene petiverella L.
H. simpliciana Haw.
H. plumbana Scop.
H. saturnana Guen.
Laspeyresia compositella Fab.

GELECHIIDAE.

Metzneria metzneriella Staint.
Gelechia mulinella Zell.
Phthorimaea obsoletella Fisch.

P. costella Westwd. (Parasite *Rhysipolis* sp. probably new.)
Brachmia gerronella Zell.
B. rufescens Haw.

COSMOPTERYGIDAE.

Chrysoclista hellerella Dup.

OECOPHORIDAE.

Carcina quercana Fab.   *D. badiella* Hübn.
Depressaria weirella Staint.   *D. alstroemeriana* Clerck.

GLYPHIPTERYGIDAE.

Simaethis fabriciana L.

ELACHISTIDAE.

Elachista atricomella Staint.

HYPONOMEUTIDAE.

Argyresthia nitidella Fab.   *Hyponomeuta padella* L.

COLEOPHORIDAE.

Coleophora nigricella Steph.   *C. glaucicolella* Wood.

GRACILARIIDAE.

Lithocolletis viminella Staint.   *Acrocercops omissella* Staint.

PLUTELLIDAE.

Plutella maculipennis Curt.   (Parasite *Angitia fenestralis* Holmgr.)

TINEIDAE.

Monopis ferruginella Hübn.   *Ochsenheimeria bisontella* Hübn.
Tinea pallescentella Staint.

HEPIALIDAE.

Hepialus lupulinus L.   *H. sylvinus* L.

Coleoptera.

CARABIDAE.

Dichirotrichus pubescens (Pk.).   *O. ardosiacus* Luts.
Calathus melanocephala (L.).   *Pterostichus madidus* (Fab.).
Dromius linearis (Ol.).   *Harpalus tardus* (Pz.).
D. nigriventris Th.   *Amara lunicollis* Sd.
Ophonus pubescens (Mull.).

STAPHYLINIDAE.

Tachyporus chrysomelinus (L.).   *Staphylinus olens* Ml.
Quedius molochinus (Gr.).

COCCINELLIDAE.

Coccidula scutellata (Hbst.).
Rhizobius litura (Fab.).
Coccinella 7-punctata (L.).
C. 10-punctata ab. *bimaculata* (L.).

C. 11-punctata (L.).
Subcoccinella 24-punctata (L.).
Thea 22-punctata (L.).

NITIDULIDAE.

Brachypterus glaber Steph.
Meligethes aeneus (Fab.).

Pria dulcamarae (Sc.).

BYTURIDAE.

Byturus tomentosus (Fab.).

SCARABAEIDAE.

Trichius abdominalis Men.

ELATERIDAE.

Agriotes sputator (L.).

CANTHARIDAE.

Malachius viridis Fab.
Cantharis pallida (Gze.).
C. rustica Fln.

Rhagonycha fulva (Sp.).
Silis ruficollis (Fab.).

CHRYSOMELIDAE.

Psylliodes dulcamarae Koch.
P. affinis (Payk.).
Phaedon tumidulum Gm.

Cassida rubiginosa Mull.
Crepidodera ferruginea Scop.

OEDEMERIDAE.

Oedemera lurida (Mm.).

Nacerda melanura (L.).

CURCULIONIDAE.

Dorytomus dejeani Fst.
Apion radiolus K.
A. aeneum Fab.
A. carduorum K.

Phyllobius viridacris Laich.
Otiorrynchus ovatus L.
Ceuthorrynchus litura Fab.
C. pollinarius Först.

Hemiptera–Heteroptera.

PENTATOMIDAE.

Sehirus bicolor (L.) nymphs.

Gnathoconus albomarginatus Goeze.

TINGIDAE.

Tingis cardui L.

NABIDIDAE.

Nabis major Costa nymph.

ANTHOCORIDAE.

Anthocoris nemorum (L.).

CAPSIDAE.

Brachyceraea errans (Wolff).
Phytocoris varipes Boh.
Capsus ater L.
Liocoris tripustulatus Fab.

Lygus campestris L.
Heterotoma meriopterum Scop.
Plagiognathus arbustorum Fab.

Hemiptera–Homoptera.

DELPHACIDAE.

Asiraca clavicornis Fab.

PSYLLIDAE.

One sp. indet.

Hymenoptera.

VESPIDAE.

Ancistrocerus albotricinctus (Zett.).

ICHNEUMONIDAE.

Angitia fenestralis (Holmgr.).
Banchus volutatorius (L.).
Glypta bicornis Boie.

Pimpla spuria Grav.
Goniocryptus plebejus Tschek.

BRACONIDAE.

Microgaster sp.

Rhysipolis sp.

Diptera.

ASILIDAE.

Dioctria atricapilla Mg.

THEREVIDAE.

Thereva ? nobilitata Fab.

STRATIOMYIIDAE.

Nemotelus notatus Zett.   *Microchrysa polita* L.

SYRPHIDAE.

Eristalis aeneus Scop.

TRYPETIDAE.

Trypeta florescentiae L.

The total number of species observed is :—

Rhopalocera	15
Heterocera	183
Coleoptera	46
Hemiptera–Heteroptera	12
Hemiptera–Homoptera	1
Hymenoptera	8
Diptera	6
	271

I wish to thank my colleagues at the British Museum (Natural History) for their help in identifying the various species and plants and Mr. T. G. Howarth for drawing a botanical map.

BOOK NOTICE.

Nature Parade. By F. W. LANE. pp. 316, 63 pls. 8vo. London (Jarrolds). (1939.) Price 15*s.*

This book contains 14 chapters arranged in 3 sections. The first is entitled Private Lives and comprises the chapters on Food, Toilet, Sleep, Leadership, Strength, War and Doctoring. The second is entitled Speed and Locomotion with the chapters on Animals, Fish, Birds, Insects, and Out of their element. The third and last has but two chapters on Animals we never see alive because they are rare or mysterious.

The author has " . . . attempted a synthesis of the more unusual observations which have been made . . . by naturalists, explorers, scientific workers, and chance observers of animals in all parts of the world." It will therefore be understood that the book has a " popular " appeal.

Among some of the statements here brought together attention may be directed to the tables of comparative speed. It is unfortunate that the table of speed of " insects " opens with the speed of a burrowing earthworm and includes several Mollusca, but it is well to know where to find such an attempt at cataloguing the speed of movement of animals.

BOOK NOTICE.

The Louse. An account of the Lice which infest man, their medical importance and control. By P. A. BUXTON. pp. ix + 115, 28 figs. 8vo. London (Arnold). (1939.) Price 7s. 6d.

This book is concerned with *Pediculus humanus* and *Phthirus pubis*. It comprises 6 chapters as follows : The Anoplura or Sucking Lice; The Anatomy of *P. humanus*; The Biology of *P. humanus*; The medical importance of *P. humanus*; The control of *P. humanus*; and The Crab Louse (*Phthirus pubis*). An appendix deals with methods of rearing and methods of feeding and infecting lice by rectal injection. A list of references extending to 7 pages and index complete the volume.

The book was originally written as part of a larger work on medical entomology designed for readers with some knowledge both of entomology and medicine. The author has, however, attempted to make it comprehensible to those who lack the one or the other. In the belief that to control an insect, full general knowledge of all parts of its life must be available, attention is concentrated more on the biology than the anatomy of the louse.

BOOK NOTICE.

Grassroot Jungles. A book of Insects. By E. W. TEALE. 8vo. London (Putnam) [n.d.]. pp. xii + 233, 130 figs. Price 15s.

In this book are illustrations of many everyday insects of North America. Most of the pictures are greatly enlarged and thereby give a wealth of detail not normally visible to the average person. The half-tone reproductions are excellent and the collection reproduced is but a small selection from the thousands of negatives made by the author.

A narrative written in popular style serves as a background to the pictures.

BOOK NOTICE.

The Mind of the Bees. By J. FRANÇON. Translated by H. ELTRINGHAM. 8vo. London (Methuen) (1939). pp. xi + 146, 11 figs. Price 6s.

This book is translated from the French. It tells the results of personal observations and experiments to discover what bees can do. The sections of the book are : the methodical organisation of the work of the bees; memory, sense of orientation and survey; bees and colours; and intercommunication between the bees.

The translator in his preface says : " At a time when even the vocabulary of Science is a mystery to the uninitiated, it is a joy to find a work which can be read with intelligence and delight by a child and yet contains material of the greatest scientific interest."

PHENOLOGICAL OBSERVATIONS ON THE BRIMSTONE BUTTERFLY, *GONEPTERYX RHAMNI* (LINN.) (LEPID.)

By G. Fox-Wilson, N.D.H., F.R.E.S., F.L.S.

(*R.H.S. Laboratory, Wisley.*)

This familiar butterfly is the first of the hibernating species to appear in early spring, and it has been suggested that the date of the first re-appearance of this species at the Royal Horticultural Society's Gardens, Wisley, Surrey, over a period of twenty years should be placed on record.

The first specimen of this so-called " editorial butterfly " to appear at Wisley is along the edge of a mixed Larch and Scot's Pine wood sloping due south, and hibernated specimens are usually to be found in certain large Holly trees which grow along the outer rim of this wood and in clumps of Ivy on some ancient Oak trees, both of which plants provide hibernacula.

This butterfly commences to fly regularly about mid-April, but in some years it has been found at Wisley on the wing in mid-February (1896, 1920), and even in December (19th Dec. 1932). It has been stated (Thompson, 1934) that a temperature of 60° F. is necessary to awaken a torpid insect, and that this temperature in winter is very fugitive, for any obscurity of the sun by cloud lowers the temperature and, incidentally, reduces the vigour of the insect. Our records show that the torpid Brimstone frequently re-awakens and becomes active on the wing at temperatures below 60° F. (*vide* Meteorological Charts).

To attempt to forecast the date of emergence of *G. rhamni* from hibernation on data based solely on the maximum day temperature is not possible; for other factors, namely the minimum night temperatures and hours of sunlight over a period of a few days prior to its re-appearance, are concerned with the renewed activity of the species. There is, of necessity, a pre-period of " warming-up " necessary to awaken the torpid insect and to induce it to leave the shelter of its hibernaculum. For instance, in 1929, the first appearance of this butterfly was on the 26th March, but an examination of the meteorological data shows that a higher maximum temperature (66° F.) was recorded on the 20th March but the minimum temperatures at this time and for a period of days prior to the 20th were low compared with those prevailing immediately prior to its re-appearance on the 26th March.

It has been mentioned that this butterfly (♂) was on one occasion seen flying in December, and this insect had been subjected to a period of " warming-up " when the maximum day temperatures during the week prior to its appearance ranged from 49–55° F., with minimum night temperatures of 29·5–49° F., with two bright days (3·6 and 2·1 hours of sunshine respectively) immediately prior to its emergence.

Records of the first re-appearance of the Brimstone butterfly have been taken at Wisley over a period of twenty years (1920–1939), and these have been correlated with the maximum and minimum temperatures and hours of sunshine for a period of seven days prior to the emergence from hibernation. Information, though available, of other meteorological data—relative humidity readings and rainfall—is not given, for a study of such data appears to show no effect on the awakening process of the torpid insect. The factors that influence the re-appearance of the species are temperature and illumination, the former including

the maximum and minimum temperatures over a period of a few days prior to the spring advent, and the latter indicating sunlight, for never has the first butterfly at Wisley been observed flying on a sunless day even though the maximum and minimum temperatures have been favourable for such an event.
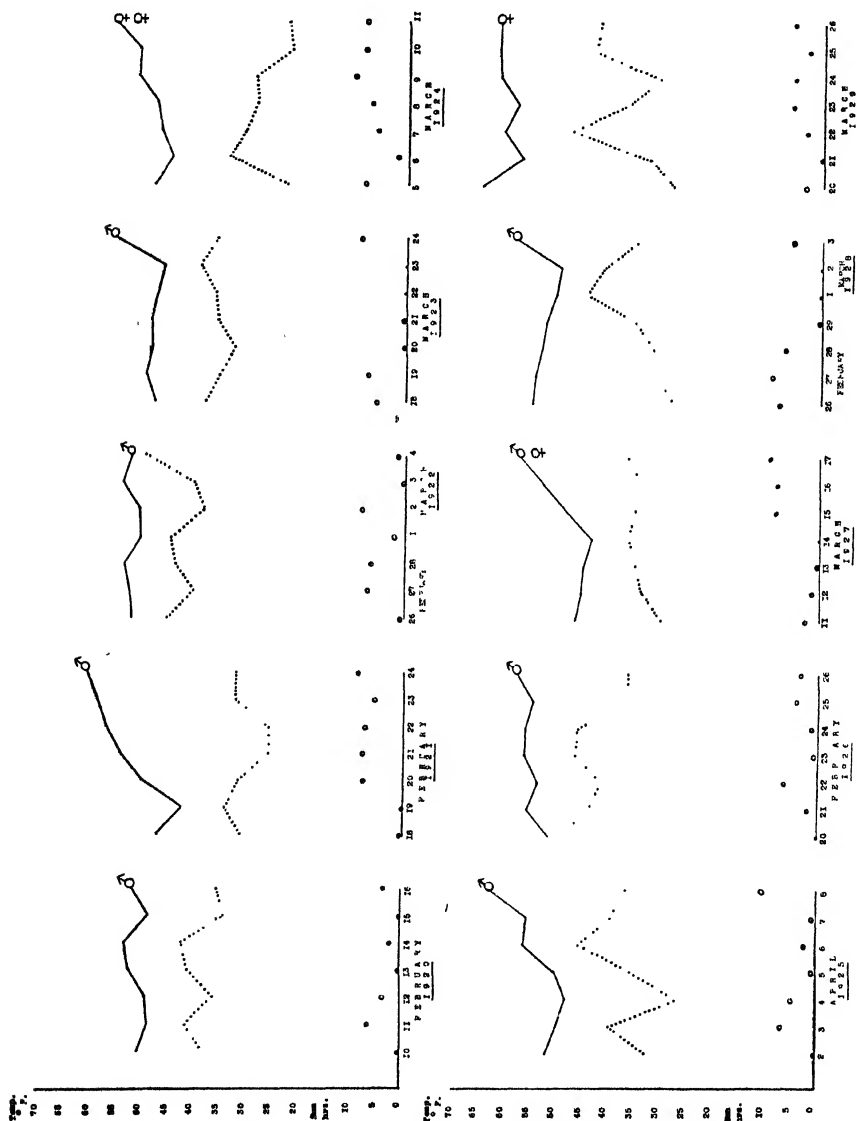
Maximum and minimum temperatures and amount of sunshine for a period of seven days prior to the first appearance of *G. rhamni* 1920–1929.

Some earlier records of the first appearance of this butterfly at Wisley were found and are herewith given. These records were made by the gardener (1909) of the late Mr. G. F. Wilson (the former owner of the Wisley Gardens),

but it is not possible to give information concerning weather conditions prevailing over this period of years.

1891	17th April.	1897	18th February.
1892	25th February.	1898	no date
1893	19th February.	1899	13th March.
1894	25th March.	1900	10th March.
1895	10th April.	1901	no date
1896	11th February.	1902	6th March.

Maximum and minimum temperatures and amount of sunshine for a period of seven days prior to the first appearance of *G. rhamni* 1930–1939.

YEARS 1920–1939.

1920	16th February	♂.		1930	22nd March	♂.
1921	24th February	♂.		1931	14th March	♂.
1922	4th March	♂.		1932	23rd April	♂.
1923	24th March	♂.		1933	11th March	♂♂♂♂.
1924	11th March	♀♀.		1934	25th March	♂.
1925	8th April	♂.		1935	20th March	♂♂.
1926	26th February	♂.		1936	10th March	♂.
1927	17th March	♂♀.		1937	5th April	♂♂.
1928	3rd March	♂.		1938	4th March	♂.
1929	26th March	♀.		1939	3rd March	♀.

SUMMARY.

The dates of the first re-appearance of the Brimstone butterfly at the Royal Horticultural Society's Gardens, Wisley, Surrey, are given for a period of twenty years.

The meteorological data—maximum and minimum temperatures and hours of sunshine—over a period of seven days prior to the appearance of this species each year are set out, and indicate the effect of a pre-period of " warming-up " that is essential to awaken the torpid insect.

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BOOK NOTICE.

Classified Index of Entomological Contributions to the *Scottish Naturalist* from its commencement in 1871 to the end of 1938. By P. H. GRIMSHAW. 8vo. (Scottish Naturalist, 1939.) pp. 65. Price 2s.

This classified index appeared in several parts in the *Scottish Naturalist.*

It is arranged by Orders and Families of insects, and the entries under each heading are arranged alphabetically by authors. The number of entries indexed is approximately 1250; entries of interest to more than one Order are usually repeated. Special note is made of all Vice-County records and a list of the Vice-Counties concerned is given in the introduction.

THE SEXUAL RATIO OF THE COMMON EARWIG, *FORFICULA AURICULARIA* L. (DERMAPT.), AS OBSERVED IN TRAP BANDS

By G. Fox-Wilson, N.D.H., F.R.E.S., F.L.S.

(R.H.S. Laboratory, Wisley.)

The gregarious habits of the Common Earwig, *Forficula auricularia* L., have been mentioned by various authors (Burr, 1939; Lucas, 1920; Worthington, 1926), and this note deals exclusively with this characteristic.

During August, September and October it is common to find assemblages, often very large, of Earwigs hiding in suitable crevices, for instance, in the uppermost internodal area of Bamboo support-canes (fig. 1), and beneath old greasebands and corrugated-paper and sack-bands, both of which are frequently placed on the stem of standard and half-standard fruit trees for the capture of the apterous ♀♀ of various "Winter Moths," and for the trapping of the adult Apple Blossom weevil, *Anthonomus pomorum* (L.), and/or the larvae of the Codling moth, *Cydia pomonella* (L.)

It is the practice at the Royal Horticultural Society's Gardens at Wisley to allow the grease-bands to remain on the stem of certain standard fruit trees (19 Apples, 10 Pears, 6 Plums—*vide* Plan) for twelve months. These bands are removed during early October each year, and are replaced by fresh bands some days later. It was found that large numbers of sexually mature Earwigs congregated beneath the old bands, and it has been our practice to collect the insects annually and to ascertain the sexual ratio of the adults (Table I and Graph).

A number of macrolabious forms—generally referred to as the variety *forcipata*—are found each year, and their number appears in Table I. Among the colonies are to be found a certain number of individuals with abnormal callipers, especially among the males. It is suggested that this abnormality is due to the cannibalistic or fighting habits of the species.

In considering the senses of the Common Earwig, Burr (1939) states that thigmotropism is stronger even than the negative phototropism to which they react, and states : " There is certainly connection between this thigmotropism and their gregarious habits. In everyday language, we should say that they derive a feeling of comfort from the contact of their kind." The dominant stimulus is, therefore, tactile.

It will be noted (Table I) that the number of Earwigs found beneath the bands in 1935 and 1938 † was the lowest on record; this being due to the stripping of the bands in July by birds, especially Jays and Great Tits, which were seeking the larvae of the Cherry Bark Tortrix, *Eucosma woeberiana* (Schiff.). During these years the larvae occurred in considerable numbers tunnelling in the bark of the several fruit trees, and more especially in the confines of the bands.

The reason for the marked fluctuations in number over the years 1928–1939 is due chiefly to parasitism by Tachinid flies (Thompson, 1928). The type of ground vegetation in the immediate vicinity of these thirty-five standard

PLAN OF STANDARD FRUIT TREES UPON WHICH THE
RECORDS OF EARWIG POPULATIONS WERE TAKEN.
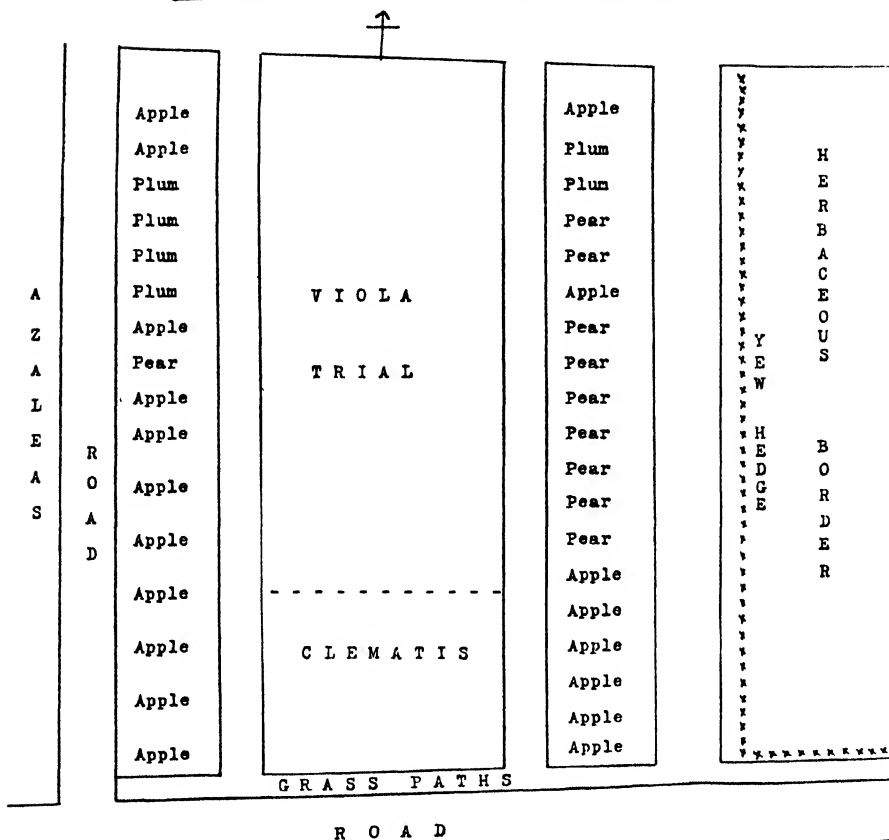
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                    ↑

          Apple              Apple
          Apple              Plum                  H
          Plum               Plum                  E
          Plum               Pear                  R
          Plum               Pear                  B
A         Plum    V I O L A  Apple                 A
Z         Apple              Pear                  C
A         Pear    T R I A L  Pear            Y     E
L         Apple              Pear            E     O
E    R    Apple              Pear            W     U
A    O            Apple      Pear     H            S
S    A    Apple              Pear     E
     D                       Pear     D      B
          Apple              Apple    G      O
          Apple   - - - - -  Apple    E      R
          Apple              Apple           D
          Apple   CLEMATIS   Apple           E
          Apple              Apple           R
          Apple              Apple

          G R A S S   P A T H S

          R  O  A  D

          Fruit trees underplanted with Iris species, Pansies and
                            Polyanthus.
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fruit trees has remained constant (*vide* Plan), so that the food of the Earwigs existing in this area has been the same for some fifteen years. We have not observed any migration of Earwigs from or to this site from other areas at Wisley, and the marking of individuals supports this. Our observations do, however, show that there exists in the Wisley Gardens several distinct and separate colonisations with little or no contact one with the other.

An attempt was made to correlate the relationship between population figures and climatic conditions, but no significant relationship appears to exist and it is, therefore, unnecessary to provide meteorological data for the years in question.

My thanks are due to my colleague, Mr. F. C. Brown, for the photograph illustrating the assemblage of Earwigs in a bamboo cane.
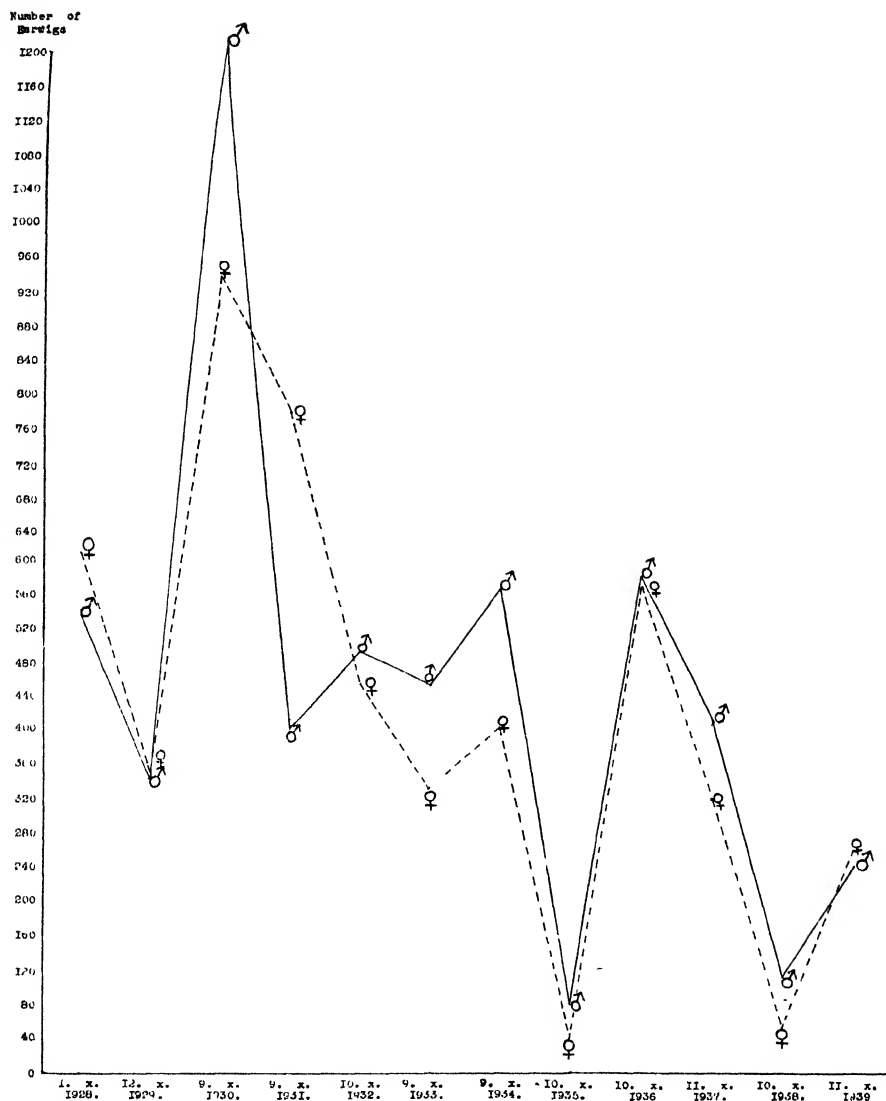
Number of *F. auricularia* (♂♂, ♀♀) captured beneath Grease-bands, 1928–1939 (see Table I).

SUMMARY.

The gregarious habits of the Common Earwig, *F. auricularia* L., are considered, together with the sexual ratio of insects found sheltering beneath trap-bands on fruit trees.

The number of macrolabious forms found in the colonies is given.

The limiting factor affecting the population is one of parasitism, and climatic conditions do not appear to exercise any marked influence on the **number of Earwigs.**

Fig. 1.—An assemblage of *Forficula auricularia* L. in internodal area of Bamboo support-cane.

TABLE I.

Date	♂♂, no.	♀♀, no.	♂♂, var. *forcipata*	♂♂, %	♀♀, %	Total
1.x.1928	534	619	11	46·7	53·3	1164
12.x.1929	349	355	3	49·8	50·2	707
9.x.1930	1207	932	9	56·6	43·4	2148
9.x.1931	410	784	1	34·4	65·6	1195
10.x.1932	499	466	8	52·1	47·9	973
9.x.1933	443	336	9	57·4	42·6	788
9.x.1934	557	406	16	58·5	41·5	979
10.x.1935	81	40	2	67·5	32·5	123†
10.x.1936	592	587	2	50·3	49·7	1181
11.x.1937	422	320	1	56·8	43·1	743
10.x.1938	117	56	1	67·8	32·2	174†
11.x.1939	247	266	2	48·3	51·7	515

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LUCAS, W. J., 1920, *Monograph of British Orthoptera* : 51–52.
WORTHINGTON, E. B., 1926, *Entomologist* **59** : 138–142.
THOMPSON, W. R., 1928, *Parasitology* **20** : 123–158.

ON THE OCCURRENCE OF MALES OF *RHODITES ROSAE* (L.) (HYMENOPTERA, CYNIPIDAE)

By E. McC. CALLAN, B.Sc., A.R.C.S., D.I.C., Ph.D., F.R.E.S.

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Introduction and Methods Used.

THE Cynipid genus *Rhodites* is represented in Great Britain by four species, the larvae of which cause galls of distinct and characteristic appearance on various wild roses. The most abundant species, *Rhodites rosae* (L.), produces the gall known as the robin's pincushion, moss gall or bedeguar. *R. eglanteriae* Htg. gives rise to the smooth pea gall, and *R. rosarum* Gir. the spiny pea gall. *R. spinosissimae* Gir., which is the rarest of the four species, produces a gall which may assume various shapes. *R. rosae* occurs throughout Europe and western Asia and also in North America. The other species are apparently confined to Europe.

The community of insects inhabiting the galls of the first three species was studied. During the autumn of 1934, 125 *R. eglanteriae* and 44 *R. rosarum* galls were collected, and an additional 85 *R. eglanteriae* galls during the autumn of 1935. These were obtained from various localities in south Buckinghamshire and from localities in Surrey and Cumberland.

A more detailed study was made of *R. rosae* galls, as it was possible to collect these in large numbers. The majority of *R. rosae* galls were collected during the winter of 1934-35, 1059 galls being obtained altogether. A few of these were collected as early as October and as late as April, but most of them, *i.e.* more than 82%, were collected in February and March. An additional collection of 79 galls was made during the winter of 1935–36. The majority of *R. rosae* galls were collected from 26 localities in south Buckinghamshire within 20 miles of Slough. Some galls, however, were collected from a number of localities in Hampshire, Surrey, Cumberland and Yorkshire.

It was found to be essential to collect galls only after the gall-feeding larvae were fully fed. The galls could then be stored and subjected to a certain amount of drying without harming the occupants. *R. eglanteriae* and *R. rosarum* galls were stored in 3-in. by 1-in. glass tubes either fitted with corks or capped with muslin. The smaller *R. rosae* galls were similarly stored, while the larger galls were kept in glass jars of various sizes capped with muslin. It was found to be an advantage to allow the galls to lie upon a layer of dry sand rather than directly on the bottom of the storage vessels. In this way, any slight amount of moisture collecting at the bottom of the vessels was absorbed by the sand, and insects appearing from the galls were always in a perfectly dry condition, which facilitated identification, and were never attacked by moulds. The tubes and jars containing the galls were stored in a small summer-house with a permanently open doorway on the south-west side. The conditions of temperature and humidity prevailing in this improvised insectary were found to approximate to those in the open air.

Only 815 of the *R. rosae* galls produced insects. In all 24,393 insects appeared

as adults; 6007 of these were the gall-causing species and the remainder were inquilines and parasites. A number of males of *R. rosae* were obtained, although the great majority were females. No males of *R. eglanteriae* and *R. rosarum* were obtained from the small number of galls of these species collected.

Previous Records.

The *Rhodites* species occurring in Europe appear to be normally parthenogenetic and males are of extreme rarity. According to Kieffer (1914) males of *R. rosae*, *R. eglanteriae* and *R. spinosissimae* have been occasionally obtained. Males of *R. kiefferi* appear to be more abundant, while the existence of males of *R. rosarum* and *R. mayri* Schlecht. seems doubtful.

Kuznetzov-Ugamskij (1930) recorded a *Rhodites* sp. in Asia, in which the males are as abundant as the females, and parthenogenesis probably does not occur.

Kinsey (1920a) suggests that in some primitive *Rhodites* species in America normal sexual reproduction may take place, but in the genus as a whole the male sex is gradually disappearing, and in consequence parthenogenesis is becoming the sole means of reproduction. He gave the percentage of males in America as 0 for *R. bicolor* Harr., 1·5 for *R. rosae*, 8 for *R. dichlocerus* Harr. and 35 for *R. ignotus* O.S.

Cameron (1892) gave a brief description of the male of *R. rosae*, and stated that it is exceedingly rare in comparison with the female. Adler (1894) obtained 7 males out of a total of 671 insects. Kieffer (1914) reared the species for several years without obtaining a single male.

Hoffmeyer (1925) is of the opinion that the male occurs rarely in Germany. He quoted the records of Adler and Kieffer, and stated that Reinhard, in rearing hundreds of individuals over a period of 15 years, only obtained one male, and that according to Riedel the proportion of males to females is 1 : 100. Hoffmeyer obtained two males and at least 221 females from galls collected in Denmark. Some of the galls were collected late in the spring, so that some males may have already left the galls prior to collection. He repeated his experiments, collecting galls in two subsequent years from various localities in Denmark, and obtained altogether 137 males and 3288 females.

Picard (1926) also referred to the records of Adler, Kieffer and Reinhard, but made a mistake in saying that Adler obtained 7 males to 671 females, whereas 671 insects only were obtained altogether, of which 7 were males and 664 females. Picard pointed out that the results of Magretti, who claimed that in Italy the males were much more numerous than the females, cannot be accepted, as it is practically certain that the inquiline, *Periclistus brandti* Ratz., was mistaken for the male of *R. rosae*. As further suggesting that an error was made in identification, Picard showed that Magretti does not record the inquiline as occurring in Italy, which would otherwise be difficult to explain, as *P. brandti* is particularly abundant in southern Europe and is recorded from Italy by Tavares (1920). Picard acquired galls from various parts of Europe in order to obtain males, and stated that so considerable a number of females appeared that he gave up counting them. He obtained 4 males, however, although the number of females exceeded 2000.

Kinsey (1920b) stated that in America males and females are sometimes produced in about equal numbers, but other galls yield no males at all. His final average gave 1–2% of males, which agrees with observations made in Europe.

Dr. K. S. Dodds informs me (1938, *in litt.*) that he reared numerous females from galls in England without obtaining a male. In the U.S.A. he later obtained

males from a number of galls, usually a gall which produced males only yielding this sex. This would suggest the occurrence of unisexual families, but is not in agreement with my results in England, in which one of nine male-producing galls yielded only males and the others females and males.

Males Reared from Galls in England.

The *R. rosae* galls produced females in great abundance and males extremely rarely, and there can be no doubt that the species is normally parthenogenetic. From 815 galls 6007 specimens of *R. rosae* were obtained; 46 of these were males and 5961 females. This gives the sex ratio as the proportion of males to females as 1 : 130 and the percentage of males as 0·8.

The males were obtained from only nine galls from various localities as shown in Table I.

TABLE I

Locality	No. of galls pro-ducing females	No. of galls pro-ducing males	No. of males obtained
Farnham Common, Bucks .	121	3	30
Hitcham Park, Bucks . .	98	2	6
Littleworth Common, Bucks .	38	1	3
Corhampton Downs, Hants .	13	1	3
Hedgerley, Bucks . .	36	1	2
Stoke Common, Bucks . .	2	1	2

It is remarkable that the three male-producing galls from Farnham Common, Bucks, yielded a total of 30 males, two galls each producing 6 and the remaining one 18 males. No other galls produced more than 3 males per gall. The gall from Littleworth Common, Bucks, produced only males, all the other male-producing galls yielding females together with males. A second collection of galls was made from Farnham Common in the following year. The collecting of the previous year had reduced the *Rhodites* population in this locality, and only 26 galls were found as against 232 in the previous year. These galls unfortunately did not yield any males.

Galls were successfully obtained by encaging *R. rosae* females on shoots of *Rosa canina* L. growing in pots in a heated glasshouse. Twelve insects eventually appeared from these galls, and it is remarkable that one of these was a male (see Experimental breeding of *R. rosae*).

Table II shows the relative abundance of males and females, expressed as sex ratios and percentages of males, obtained by various authors.

TABLE II.

Country and author	No. of males and females	No. of males	Percent-age of males	Sex ratio males : females
Germany : Adler (1894) . . .	671	7	1	1 : 95
U.S. of America : Kinsey (1920) . .	419	6	1·5	1 : 69
Denmark : Hoffmeyer (1925) . .	3425	137	4	1 : 24
France, England, Italy, Denmark, Sweden : Picard (1926) . . .	2000	4	0·2	1 : 500
England : Callan	6007	46	0·8	1 : 130

The majority of the males were found dead in the storage vessels some time after they had appeared from the galls, and their time of appearance is unknown. During the course of the investigation a large number of galls was dissected, and the larvae removed and kept in individual gelatin capsules in the laboratory. Five males were obtained from such larvae removed from two galls. Actually 309 adults were obtained by this method, 5 being males and 304 females. The date of emergence from the pupa of two of these males was 9 May and 7 June 1935, the other three emerging between these dates.

A number of galls was isolated from the main bulk of the collected material, and observed, usually daily, for the appearance of insects for a period of 14 weeks. One of the galls produced 6 males. One of these appeared on 9 June, three on 22 June and two on 28 June 1935. Females started to appear from these galls on 14 May and continued for 65 days until 17 July 1935. There was a very clearly defined peak of appearance on 1 July. This was thought to be determined by the first hot day of the year, which occurred 9 days previously on 22 June, when a maximum shade temperature of 29° C. (84·2° F.) was recorded. The times of appearance of the males were therefore distinctly earlier than the date of peak appearance of the females.

A number of specimens of reared *R. rosae* males have been placed in the collection at the British Museum (Natural History).

Experimental Breeding of *Rhodites rosae.*

Numerous attempts have been made to breed *R. rosae* on the wild rose. These have apparently not always been successful, for Dr. K. S. Dodds informs me (1938, *in litt.*) that he made repeated endeavours to breed this species, but did not observe oviposition and no galls resulted.

In 1935 the experimental breeding of this species was attempted on a small scale on plants of the wild rose, *Rosa canina* L., growing in pots in a heated glasshouse. Rose shoots bearing various numbers of buds were encaged in large glass tubes with the ends closed by muslin or cotton wool. Females reared from stored galls were introduced into these tubes and observations made of their behaviour.

Three individuals incubated from a gall were introduced on to a rose shoot on 15 February, 1935. They were somewhat sluggish, but were observed with their ovipositors inserted into buds and seemed to be engaged in egg-laying, remaining in this position for as long as 30 minutes at a time. The first definite signs of gall formation were not observed until 25th April, *i.e.* 70 days after the introduction of the insects. Two galls were produced, which were kept under close observation and developed rapidly, appearing fully formed on about 10th May, at a time when no galls are to be found under natural conditions in the field. No insects were obtained from these galls.

Further breeding experiments with females incubated from galls were carried out in May and June, and 21 galls in all resulted. Oviposition in the buds was frequently observed, and eggs were found within the buds on dissection. At this time of the year the first signs of gall formation were observed from 12 to 36 days after the introduction of the insects, gall formation being more rapid in breeding experiments in late May and June than those in early May. In a number of experiments no galls resulted.

From the 21 galls only 12 specimens of *R. rosae* were obtained, but it is remarkable that one of these was a male. This male developed from an unfertilised egg laid by a parthenogenetic female. As far as I am aware this attainment is without precedent for the species. It has always been regarded

that *R. rosae* exhibits thelytokous parthenogenesis, in which the unfertilised eggs give rise solely to females. The production of this male from an undoubted unfertilised egg is of great interest, and demonstrates that the species shows amphitokous parthenogenesis, in which the unfertilised eggs give rise to either sex. Unfortunately no cytological examination of this male was made.

The females obtained were rather smaller than usual, and presumably unfavourable conditions had prevented the larvae from obtaining food sufficient for normal development. These conditions were doubtless responsible for so few galls yielding insects. The presence of a male may possibly be correlated with the conditions of semi-starvation in the gall. It would be of the greatest interest if this correlation between the production of males and unfavourable conditions existed in nature.

Geographical Distribution of Males.

The females of *R. rosae* occur apparently throughout Europe, their distribution being dependent, according to Harrison (1922), on that of their host-plant, the wild rose. Widely different sex ratios have been obtained in various parts of Europe, and it has been suggested that males may be more abundant in some regions than in others.

Hoffmeyer (1925) is inclined to the view that males may be more numerous in the north of Europe than in the south, as he obtained a higher percentage of males in Denmark than had previously been obtained in more southern countries.

Picard (1926), having previously obtained a certain number of males from Montpellier, France, was originally of the opposite opinion, believing that males might be more abundant in southern Europe. He obtained galls, therefore, from southern Italy, England, Denmark, Sweden and various parts of France, hoping to make a statistical analysis based on numbers sufficiently large to support or disprove his theory. Unfortunately he only obtained four males altogether, one of which came from Italy, another from France and the remaining two from Sweden. He concluded from his results that males are everywhere rare, as much in the south as in the north.

In many insects and other Arthropoda two distinct geographical races within a single species have been found to exist, one in which males are extremely rare or absent and reproduction is parthenogenetic and the other in which males are numerous and bisexual reproduction normally occurs. In most cases the parthenogenetic race is more northern in distribution than the bisexual race. Vandel (1931) has fully discussed this phenomenon, to which he originally gave the name geographical spanandry, but which he now terms geographical parthenogenesis.

On the examination of my results in conjunction with those of other authors, it is difficult to draw any conclusion other than-that the males are rare wherever they have been found. If anything, some slight support is given to the view that males are more abundant in the north than in the south. It would be necessary to make a careful analysis of the numbers of males and females, obtained from a large number of galls from all parts of Europe, before it could be shown whether or not this is true.

In the more primitive CYNIPIDAE the males and females are equally abundant, and the more or less complete disappearance of males in *R. rosae* and other specialised forms is a secondary phenomenon, consequent upon the development of parthenogenesis in the females. If males were actually more numerous in the north than in the south, speculations might be made as to whether this retention of a more primitive condition would be of any advantage to the

species living in northern latitudes. It seems certain, however, that *R. rosae* is everywhere parthenogenetic and does not exhibit any form of geographical parthenogenesis.

Summary.

From 815 bedeguar galls from England 6007 specimens of *Rhodites rosae* (L.) were obtained; 46 of these were males and 5961 females, the sex ratio being 1 male : 130 females and the percentage of males 0·8.

The times of appearance of the males from the galls were distinctly earlier than the date of peak appearance of the females.

In breeding experiments a single male developed from an unfertilised egg, demonstrating that the species exhibits amphitokous parthenogenesis.

Males are rare wherever they have been found. It seems certain that the species is everywhere parthenogenetic and does not exhibit any form of geographical parthenogenesis.

Acknowledgements.

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BOOK NOTICE.

Destructive and Useful Insects. Their habits and control. By C. L. METCALF
and W. P. FLINT. 8vo. London (McGraw-Hill), 1939. Second edition.
pp. xvi + 981, 584 figs. Price 50s.

In 1928 appeared the well-known work *Destructive and useful insects* and in
the decade which has elapsed since its appearance such sweeping change has
taken place in entomological practice that it has been found necessary to revise
the work completely so that it has in fact been re-written. This has resulted in
about twenty per cent. more material being provided than was the case in the
first edition.

One of the new additions is the attempted key to the identification of the
immature stages of the orders of insects.

The 23 chapters of the book are entitled : insects as enemies of man; the
value of insects to man; the external morphology of insects; the internal
anatomy and morphology of insects; the mouth parts of insects; development
and metamorphosis; the place of insects in the animal kingdom; the orders of
insects; insect control; apparatus for applying insecticides; insects injurious
to corn and related crops; insects injurious to small grains; insects injurious
to legumes; cotton insects; tobacco insects; insects injurious to vegetable
gardens and truck crops; insects injurious to deciduous fruits and bush fruits;
citrus insects; insects attacking shade trees and shrubs; insect pests of
greenhouse plants and the flower garden; household insects and pests of
stored grains, seeds, and cereal products; insects injurious to domestic
animals; insects that attack and annoy man and affect his health.

A noteworthy feature of the book is the great assistance offered to the
reader by the provision of many tables, synopses, keys, and field keys. The
field keys are presented under the heading of the affected crop.

The index extends to more than 70 pages of double-column matter.

BOOK NOTICE.

The Moths of the British Isles. By R. SOUTH. Edited and revised by H. M.
EDELSTEN. 2 Volumes. 8vo. London (F. Warne & Co.), 1939. Price
10s. 6d. each volume.

The standard work of its kind in this country is South's *Moths and Butterflies*
originally published in 1907 and 1908 and re-issued at frequent intervals. Its
appearance as a new and revised edition will be welcome to many.

Perhaps the most obvious change in the book is the introduction of a more
modern nomenclature for the species and genera.

The popularity of the book, which is proved by its long life as a standard
work, has doubtless been the cause of the absence of any change in the general
lay-out and presentation. The many coloured illustrations are still given for the
benefit of the reader and a welcome addition is the provision of more extensive
indices.

To each volume is appended an Appendix which brings the subject matter
right up to date. On page 336 of volume 1 is described a new aberration " for
which we propose [the name] ab. *aeruginis.*" It is nowhere stated who " we "
are. As, however, the title-page states that Mr. H. M. Edelsten is responsible
for the revision, he should be cited as the author of this new aberration.

BOOK NOTICE.

Working with Nature. By E. KING and W. PESSELS. pp. xviii + 181, 60 figs.
8vo. New York and London (Harper Bros.) (1939). 6s.

This is a book on the conservation of wild life approached from the ecological
standpoint. It is of popular appeal, and opens with an attempt to capture
the reader's imagination by presenting familiar everyday creatures in a new
light. A large part of the book concerns the insects. The chapters are
entitled : What's going on in your dooryard ? ; In debt to the insects ; Butter-
flies and moths ; Beetles ; In Pond and Brook ; Knowing the birds ; Saving
the ducks ; What the fur-bearers mean to us ; The beaver—our first
conservationist ; Our big game. There is an appendix on further aids to
conservation, with a list of books to read.

BOOK NOTICE.

Les Guêpes. By L. BERLAND. sm. 8vo. Paris (Éditions Stock) (Les Livres
de Nature), 1939. pp. 166 + [i]. Price 18 francs.

This work of popular appeal is divided in two parts. The first deals with
solitary wasps and the second with social wasps.

The six chapters of the first part deal with : the life of the wasp ; the work
of wasps ; the prey of wasps ; paralysis of prey by wasp poison ; fixity of in-
stinct ; wasps which exploit others.

The three chapters of the second part deal with : the communities of
wasps ; wasp nests and how they are made ; the feeding of wasps.

BOOK NOTICE.

A Laboratory guide in Entomology for introductory courses. By R. MATHESON.
4to. Ithaca (Comstock Publishing Co.), 1939. pp. vii + 135, 54 figs.
Price $2.00.

This book is by a Professor of Entomology at Cornell University and is
based largely on the work offered in the " beginning course in Entomology at
Cornell University."

The book is divided in twenty-eight chapters, with an Appendix on how to
collect, prepare, preserve, mount and rear insects, and a glossary.

The book is so made as to be particularly suitable for its purpose of a labor-
atory guide since each page may be easily detached by tearing along the per-
forations at the back. A series of larger holes is presumably supplied to enable
the pages torn out to be returned to their place in the book. The book is bound
in a semi-stiff cardboard cover.

A noteworthy feature of the work is the large number of line drawings
provided, many of them being printed on one side of the paper only.

AN EXPERIMENT AND SOME OBSERVATIONS ON *VESPA CRABRO* L. (HYMEN., VESPIDAE)

By R. G. SANDEMAN, F.R.E.S.

DURING the last five years the Hornet has become increasingly common around Crickhowell, Breconshire. At one time it was an uncommon insect, and it was unusual to find a nest; now, however, it nests in some numbers, and seems to be increasing. I found no fewer than 14 nests in hollow beech trees in Llangattock Park near here in September 1937. This was an exceptionally large number but one can always find five or six nests every year.

Not only do they nest in hollow trees, which is the typical situation, but also in overhanging river banks, old buildings, fern ricks, and even in the ground, this last situation being most unusual. Contrary to popular opinion, the Hornets are by no means ferocious insects, and one can watch them at close quarters with perfect safety if one is quiet and confident.

To take their nests together with the swarm is, however, a task not to be lightly undertaken. I had long wished to get a life-history of the nesting habits of this species, and last year (11th June, 1939) I had the good fortune to find an embryo nest containing only the queen, situated in the ground.

A friend and I conceived the idea of digging out the comb and transferring it to a box together with the queen, where we could observe the whole social economy of the nest from start to finish. We first timed the departure of the queen and found that she left the nest sufficiently long for us to get out the comb and hang it in a box with a wire passed through it before she came back.

We therefore set to work immediately she left the nest and in about ten minutes we had succeeded in transferring the little comb to the box, and placing the box in the hole where she could see it.

The comb was a typical embryo nest, containing a little group of some twenty cells with larvae and eggs, placed in a little bell-shaped cup of coarse yellow paper composed of the typical rotten wood pulp. It was about 9 inches in circumference.

We had just finished when the queen came back. We never for a moment thought she would take to her new situation, and she flew round and round, hovering low over the grass, and then, widening her circles, seemed quite at a loss as to the position of her nest. Time after time she hovered almost at the entrance to the box, but kept passing it and continued to search along the ground to right and left. She then visited and entered various mouse-holes nearby, evidently mistaking them for the entrance to her nest, then after a few moments emerged and continued her search. This went on for about twenty minutes, and she now appeared hopelessly lost.

At this point we decided on a desperate experiment! Waiting until she entered one of the mouse-holes, we moved the box and placed it over the hole. After several attempts we were able to slide a sheet of glass under it, and finally got her into the box as she emerged from the hole. In lifting the box, however, she escaped and flew straight off. We certainly never expected to see her again after this!

However, to our astonishment and delight, she returned in about five minutes! Again she went down the mouse-hole and once more we got the box over the hole and slid the glass beneath it. This time we succeeded in capturing

her, but her frantic efforts to get out, flying about in the box and up and down the glass, boded ill for her settling down.

Suddenly, however, she alighted on the comb and sat quietly there on the cells with her abdomen and antennae all trembling. We then very quietly placed the box in the excavation where we had dug out the nest, and after packing the soil around it removed the glass. During this operation she remained on the comb, and was still there, apparently quite at home, when we left at 5 p.m.

Returning at 5.30 p.m. we found her still seated on the comb.

The following observations are copied from my notebook :—

5.56 p.m. . . . Queen left nest. Flew round in ever-widening circles and then straight away over house.

6 p.m. . . . Returned and found her new situation beautifully, making only a few circling movements before she entered box and alighted on comb. She carried a large pellet of building material in her mouth. I was able to watch closely from only two feet distant what took place. She went to each cell containing larvae, and poked her head into each one. This, I am convinced, was to moisten the pellet further with the juices from the mouths of the larvae. It could not have been to feed them, because the pellet she carried was of building material and not food. She then applied the pellet to the broken case of the comb, and quickly filled in a small hole. After this, she settled down quietly on the comb and was still there when I left at 6.25 p.m.

My next visit was at 7 p.m. She had evidently been out again, as a wet strip of new paper had been added to the edge of the comb case.

10.15 p.m. . . . Queen settled down for night in comb.

12th June.

9 a.m. . . . Queen now thoroughly at home sitting on comb and had added more material to case.

12 noon. . . . Entered nest with practically no hesitation. Came in up wind. Went inside, then came out and applied large pellet to edge of case, which had been considerably worked upon since the morning. She built quickly, with vigorous movements of her mandibles, only taking one minute to finish the strip. Went inside comb.

12.53. . . . Queen left nest and flew over Park in direction of clump of trees.

I returned at 1.45 p.m. She was inside comb.

1.51 p.m. . . . Queen left nest, flying over Park. The case had now been extended downwards till the cells were hidden, and one could not see what took place inside.

1.59 p.m. . . . Entered nest but did not build.

2.11 p.m. . . . Left nest, circled round twice, then flew up over house. This time while she was away we placed a small mirror in the bottom of the box so that the inside of the comb was reflected in it, and we were thus able to see all that went on and which would otherwise have been hidden by the case.

2.23 p.m. . . . Queen returned with a pellet and built in two places very quickly on case.

2.29 p.m. . . . Left nest flying in usual direction over Park.

2.38 p.m. . . . Came in. The cells, larvae, and all details were beautifully reflected in the glass. She carried a large pellet and went to the cells and put her head in, apparently moistening the pellet with the juices from the mouths

of the larvae. She then built on comb case and then on a cell wall to heighten it. Afterwards cleaned her antennae by drawing them through her mandibles and front legs. Attended larvae. Went up behind comb and rested. Still resting when I left at 3 p.m.

I returned at 7 p.m. to find the queen sitting quietly on the cells containing larvae. Since last observation she had added about half an inch of paper to case of comb, and was now resting quietly on cells with wings along sides of body. Presently she commenced to go from cell to cell attending to the larger larvae. She put her head into each cell and with gentle, flickering, trembling, movements of her antennae seemed to be caressing the grubs. Only the larger larvae were treated in this manner.

At 7.20 p.m. she left the nest and flew over Park.

7.28 p.m. . . . Came in with large pellet, moistened it at mouth of larvae. The juices could be seen coming from their jaws. She then built at edge of comb case. Went back when pellet was half used up and again moistened it in same way, then built again. Went and attended to larvae and also went up behind comb and built at edge of a cell for some minutes.

7.39 p.m. . . . Left nest and flew over Park.

7.48 p.m. . . . Came in carrying piece of rotten wood about half an inch long held between her jaws like a dog carries a bone. Sat on comb and rapidly chewed this up into a large pellet, which she applied to comb case and then to a cell wall. Preened herself and again built at cell wall. Still in nest when I left at 8 p.m. A visit to nest at 10 p.m. revealed the fact that one of the larger larvae had spun up. The queen was tending the others.

13th June.

Commenced observations at 12.29. Queen absent. The case of the comb had by now been brought down about an inch, but there was still a wide opening at the bottom which allowed the comb inside to be well seen reflected in the glass at the bottom of the box. The comb case was composed of one single continuous sheet of coarse paper typical of the Hornet. Rotten wood pulp was the chief material, with a few sand-grains cementing it.

12.42. . . . Queen came in, flying round several times before settling. She went to the cells and sitting there proceeded to chew a large pellet, then built a small strip to case of comb. Went back and up to top of nest behind comb, where she applied remainder of pellet to strengthen the little stalk of material holding comb to the top of case. Came out again on to comb and cleaned her antennae, drawing them through her mandibles, and drawing her front legs over her head in the exact manner of a cat washing herself! This is a typical habit of wasps. I also observed that another of the larvae had commenced to spin its cocoon. It worked with a circular motion of its head as it spun. As it worked the delicate silk covering to the top of the cell grew before my eyes. The queen meanwhile tended the larvae, but did not visit the one spinning up.

1.4 p.m. . . . Queen left nest and flew in usual direction over the Park. I then ceased observation.

4.3 p.m. . . . Queen came in with a large piece of rotten wood, sat on comb and reduced it to a pellet, then built a strip to case, taking about two minutes. Tended young larvae, poking her head into each cell and caressing them with quick flickering movements of her antennae.

4.12 p.m. . . . Left nest and flew over Park.

4.21 p.m. . . . Came in after flying round a little, applied large pellet to

comb case, tended young; she now spent more time tending larvae and did not build so much.

4.37 p.m. . . . Left nest; this time she flew up into a flowering acacia tree about fifty yards away. Amongst these flowers were many Diptera and other insects.

4.38 p.m. . . . Came in with a large object in her mouth, sat on comb and reduced this to pulp. This object was some insect caught in the acacia tree. She went from cell to cell and carefully fed each larva, placing a small portion in each of their mouths. On each of the larvae could be seen a small dark spot of this food, which quickly disappeared as they eagerly fed upon it.

4.44 p.m. . . . Left nest and flew over pond.

4.51 p.m. . . . Came in after flying round six times, carrying large pellet; built on case of comb, then added to the support-strip of material to which the comb was suspended. Then attended to larvae, appeared to be feeding them with liquid from her mouth. I saw her go to one larva and gently stroke and pat it with her front tarsus, with a delicate kneading sort of motion, the larva moving its head about in a circular movement.

5.9 p.m. . . . Left nest and flew up into acacia tree.

5.15 p.m. . . . Came in with a large pellet and fed it to larvae, evidently an insect caught in the acacia tree, which seemed to be its chief hunting ground.

5.25 p.m. . . . Left nest.

5.27 p.m. . . . Came in with small pellet and built behind comb, and tended young.

5.39 p.m. . . . Left nest and flew up into acacia tree. I went over to it, but could not see her. She was back at the nest at 5.50 and feeding young.

14th June.

12.30 noon. . . . Case of comb had now been brought down to complete first layer of embryo nest. From a former experience I know that from this point the queen does not add any more to the nest, building operations being taken over by the workers as they hatch out. The only work the queen does from now on is to lay eggs, and feed the young grubs till the first workers arrive.

The opening at the bottom of the nest was now $2\frac{1}{2}$ inches wide; three of the largest larvae were spun up in a group in the centre of the little slab of comb.

It now appeared certain that the experiment would be a complete success, and that I should obtain a full life-history of the nest. Alas! It proved otherwise. The queen was not present when I visited the nest at 12.30. I waited an hour but she did not appear, nor did I ever see her again. She may have been killed by a bird, or maybe some human just " killed another of those hornets ! "

I think the outstanding fact proved by this experiment is the really remarkable attachment of the queen Hornet to her nest. When the workers are present, of course, it is an easy matter, apart from the somewhat dangerous nature of the work, to transplant a nest to a new situation, but I have never heard of any Entomologist who has done this [1] with an embryo nest containing *only the queen*. This is the second time I have done this and in each case only an unfortunate accident has prevented my obtaining a life-history of the nest from start to finish. Here is an opportunity which will fully repay any of our Fellows who cares to take it up.

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[1] [*Cf.* Janet, 1895, *Mém. Soc. zool. France* **8**.—EDITOR.]

VESPIDAE FROM MAFIA ISLAND, EAST AFRICA (HYM.)

By Desmond Vesey FitzGerald, F.R.E.S.

THE following notes are based on a small collection of Social wasps collected on the Mafia island group during 1936. The Mafia group constitutes the southern-most of the islands lying close to the coast of Tanganyika Territory, the other two being Zanzibar and Pember. The largest island, Mafia proper, is situated across lat. 7° 50′ south and long. 39° 80′ east and is only about 13 miles from the mainland at the nearest point. While it is probable that other species of wasps occur in Mafia, the present collection is representative of the commoner forms. It is not surprising, in view of the proximity of the mainland, that the species represented on the island are also common throughout the coastal districts of Tanganyika. Records of specimens collected in East Africa are included in the present paper in order to emphasise this point.

I am greatly indebted to Dr. J. Bequaert for identifying the material collected.

Polistes marginalis var. *africanus* P. de B.

This species is one of the most abundant throughout the islands, especially on the little, closely cultivated, island of Tchole, where it is by far the commonest wasp. The wasp is predacious on Lepidopterous larvae, and the mixed growth of annual herbs and vines following cultivation, provide a rich feeding-place for such larvae. This wasp is a foliage-nester, the naked comb being usually found suspended from, and sheltered by, a broad leaf. The lower surface of the pinna of a coconut leaf is a very usual site. A rather curious site in which several combs of this species were collected was under the roof of the porch of disused nests of the weaver bird, *Ploceus nigriceps* Rüpp. This connection between the bird and wasp seems to have been entirely by chance, but it is worth placing on record in view of the more intimate relations which exist between such partners elsewhere.

The comb is roundish or elongate and is supported by an eccentric, highly varnished pillar 2–3 mm. in length. The initial cell is constructed at the end of this pillar and subsequent cells are placed at the side of the older ones. At first the cells are pocket-like, several are constructed at the same time and an egg is laid in each at once. Later the cells are enlarged. The cells widen out slightly from the base towards the mouth. The length of a full-sized cell is 16 mm. and the diameter at the mouth is 2·5 mm. The material employed is a pliable, rather loosely woven, grey "paper." The pupal caps are white and semi-transparent, slightly convex and fill the mouth of the cell.

One small nest composed of five pocket-like cells was attended at the time of collection by a single female. The largest nest collected comprised thirty-nine cells. Drops of honey stored in a few cells were noticed in two nests. The larva is parasitised by a Tachinid, *Anacamptomyia africana* Bischof. The fly maggot emerges from the full-grown wasp grub and then pupates within the cell of its host. The puparia completely fills the cell, and viewed from the open end appears as a convex brown cap within the month. The parasitised nest was taken on the mainland near Dar-es-Salaam.

Specimens of this wasp were collected in the following localities : MAFIA Is. : Kilindoni, 3.vii.36, 7.vii.36 ; MAFIA GROUP : Tchole Is., 8.vii.36 ; and in TANGANYIKA : Dar-es-Salaam, 4.vi.36 ; Bagamoyo, 15.vi.36 ; Morogoro, 3.v.36 ; and Uluguru mountains, at 3000 ft., 31.v.36.

Polistes madecassus var. *fastidiosus* de Sauss.

A single colony of this species was found under the eaves of the lighthouse buildings at MAFIA Is. : Ras Mkubi, 12.vii.36. The fact that such a large and conspicuous wasp was encountered only on this single occasion on the island indicates that this species is a casual immigrant to the island.

Polistes smithii de Sauss. typical form.

MAFIA Is. : Kilindoni, 3.vii.36 and 7.vii.36 ; MAFIA Is. : Utende, 8.vii.36.

Ropalidia tomentosa (Gerst.).

This species is also a foliage-nester. The single comb examined was elongate, two cells wide and supported by a rather stout, 4-mm. long, slightly varnished pillar from about the middle of its length. The initial cell was subtended by the pillar and the next cell was constructed at the side of the first, the third cell in the angle between the first and second. Subsequent cells were similarly placed in the angle between the previous two so that they were arranged in alternate series first right then left, the twenty-two cells forming a comb 42 mm. long and about 5 mm. wide. The individual cells varied very much in depth since some were new, pocket-like and contained an egg. Others were enlarged to fit the size of the larva which they contained. Those containing pupae were full sized, 13 mm. deep and 3 mm. in diameter. The old vacated cells were in various stages of being cut away. The cells are sharply hexagonal. The material employed for cell construction is a rather hard, rather closely woven " paper " which is laid down in circular bands of various colours so that the cells appeared to be zoned pink, yellow, grey and brown. The pupal caps are semi-transparent lightly peppered with fragments of " paper " and convex in shape, filling the mouth of the cell. When first constructed the bottom of the cell is entire, but when the larva is approaching full size, or possibly earlier, the bottom of the cell is perforated with a large irregularly circular hole which is " glazed " over with a semi-transparent membrane. The presence or absence of this " window " in the bottom of the cell at once indicates if any particular, pocket-like, cell is a newly formed one or an old one cut down. This species is parasitised by a dipteron which pupates within the cell of its host and is probably the same as that recorded from *Polistes marginalis*.

Specimens from : MAFIA Is. : Kilindoni, 5.vii.36 ; MAFIA GROUP : Tchole Is., 26.vii.36 ; and in TANGANYIKA : Dar-es-Salaam, 8.vi.36 and Dondo, near Dar-es-Salaam, 28.vi.36.

Ropalidia nobilis (Gerst.).

The comb of this species, which was examined, was situated under the eave of a house. The comb of twenty-four cells was more or less circular and it was supported by a pillar subtending the initial cell, which was located near the margin of the comb. The size of the cells varied, some being pocket-like ; those containing pupae were 15 mm. deep and 4 mm. in diameter and old cells were in various stages of being cut down. The cells of the present species also resemble those of the last in the texture of the paper, the zonation of colouring, pinkish,

however, predominating, and in their sharply hexagonal sides. The pupal caps are rather flat and they are situated just within the mouth of the cell. These caps are opaque and ornamented on the outside with fragments of " paper " which appear in some cases to be derived from the partially cut-down rim of the mouth which extends beyond the pupal cap. " Windows " occur in the bottom of full-sized cells.

Specimens were collected at : MAFIA : Kilindoni, 3.vii.36; and in TAN-GANYIKA : Dar-es-Salaam, 8.vi.36; and Morogoro, 29.v.36.

Ropalidia cincta (Lep.).

A comb of this species was situated under the eaves of a house and another was located under the pinna of a coconut leaf. The first comb comprised twenty-four cells; it was leaf-shaped; the stout, flattened, 4-mm. long stalk being located on the margin at the point where the comb was narrowest. As in the case of the two previous species, the cells were variable in depth, the vacated ones being cut down. The texture of the paper, the zonation of colours, the predominance of pink and the sharp angles between the walls of the cells were also noticeable characters of the cells of this species. Pupal caps were not available for examination, but the windows in the bottoms of the full-sized cells were present.

Specimens from : MAFIA Is. : Kilindoni, 7.vii.36; MAFIA Is.: Chaki-Chaki, 21.vii.36; and in TANGANYIKA : Dar-es-Salaam, 8.vi.36; Bagamoyo, 15.vi.36; Morogoro, 29.v.36.

Belonogaster griseus (Fab.).

This was the only species of the genus collected in the archipelago. Speci-mens were taken at : MAFIA Is.: Kilindoni, 5.vii.36; and MAFIA GROUP : Tchole Is., 8.vii.36.

The following solitary VESPIDAE were also collected on the islands : *Eumenes melanosoma* var. *longirostris* Gerst. MAFIA Is.: Mrali, 10.viii.36. A " pot " of this species examined at TANGANYIKA TERRITORY : Morogoro, was composed of very " glazed " chocolate-coloured mud. An unusual feature of this specimen was that the flanged neck, which is always constructed by wasps of this genus and is used as an opening during the storing of the cell, was sealed up and left intact on the full cell. In the case of other species this neck is usually removed from the fully stored and sealed cell. The young wasp emerged through a hole bitten in the side of the " pot."

Other species collected were : *Eumenes maxillosus* (Deg.) typical form, MAFIA Is. : Kilindoni, 17.vii.36; *Synagris analis* de Sauss., MAFIA Is. : Kilindoni, 7.viii.36; *Odynerus (Rynghium) lateralis* var. *unicolor* v. Schulth, MAFIA Is.: Mrali, 10.viii.36; *Rhynchalastor fuscipennis* Meade-Waldo (=*Odynerus ferrugineus* var. *mafiensis* v. Schulth), MAFIA Is. : Hongoro, 11.vii.36; *Labus natalensis* de Sauss., MAFIA Is. : Hongoro, 11.vii.36.

BRITISH LEPIDOPTEROUS COCOONS WITH VENTILATION (?) HOLES

By C. N. HAWKINS, F.R.E.S.

1. Two cocoons of *Eriogaster lanestris* (L.) were exhibited; one cut open to show the internal aspect opposite the external holes. The holes in the cocoon of this species are referred to by Borkhausen, Tutt (quoting Hewett), and probably others, and are presumably made by the jaws of the larva after the external hard shell has been completed but before it has quite solidified. In most cases, but not always, the holes are in pairs corresponding to the two larval jaws, which are not allowed to meet completely enough to finish the bite. Occasionally, however, the holes are joined into a single larger one, and in that case the assumption is that the larval jaws take a full bite. Subsequently the larva evidently spins an inner lining to the cocoon, consisting of uncemented silk, and in this there are no corresponding holes, but where these holes occur in the outer shell, and for some distance round, the silken lining is not attached, so that a space is left here between the inner and outer walls of the cocoon. Usually there are two pairs of holes in each cocoon, a pair on each side (or thereabouts).

2. A cocoon, spun in captivity, of *Hipparchus papilionaria* (L.) formed of birch leaves tightly spun together by the larva. This cocoon also has a number of holes in the birch leaves, which the larva was seen to produce by biting from the inside after the cocoon had been formed. Here again the holes are frequently in pairs, corresponding to the two jaws of the larva, which normally did not quite meet. This particular cocoon is, perhaps, unusually well covered by the birch leaves, for the species, but I have noted the same habit in other examples, though I am not aware that it has been recorded. In the case of *E. lanestris*, it has, I believe, always been assumed that the holes are for ventilation, and presumably those in *H. papilionaria* are for a similar purpose, but it may be that in both cases they also allow a certain amount of moisture from rain &c. to reach the enclosed pupa to prevent drying up.

NOTES ON BEMBICIDAE AND ALLIED WASPS FROM TRINIDAD
(HYM.: BEMBICIDAE AND STIZIDAE)

By Desmond Vesey FitzGerald, F.R.E.S.

Rubrica surinamensis (Degeer).

THIS species is the commonest and most conspicuous wasp belonging to the family BEMBICIDAE in TRINIDAD. *Rubrica* is a gregarious nester, the colonies being situated in areas of bare sandy ground exposed to the hot sun. Paths, from the surface of which all the vegetation has been worn, being very favourite sites. The female wasp burrows into the ground in a way which may be best described as resembling the method employed by a dog. The soil is scraped away with the front legs, any particularly resistant bits being torn loose with the mandibles, while the loosened particles are cast aside with the hind legs to form a fan of excavated material around the entrance of the hole. In this respect the work of *Rubrica* is essentially different from the work of *Sphex ichneumoneus* L., a wasp which often nests with the former. *Sphex* gathers up the loosened soil and, clasping the particles against the underside of the thorax, carries them a few inches away from the entrance to its hole before dumping them. Thus, by contrast, there is a clearly marked zone free from any debris between the entrance hole and the pile of excavated soil.

Rubrica always chooses the hottest part of the day, the early afternoon, during which to do the hardest work. While the females are occupied digging, the males fly round the area in circles or they may be seen at rest on objects in the vicinity. At night the males and females segregate and rest on vegetation, the former in groups of many individuals together. Newly completed burrows and those already containing a very young larva are always carefully closed whenever the female wasp goes away. When the grub is older, however, the parent wasp does not trouble to close the entrance. The method employed by the wasp to close the entrance is as follows. First the female wasp appears head first in the entrance of the burrow and starts scraping loose particles towards herself. As the entrance fills up she comes farther and farther out, all the time alternating the action of scraping up soil with periods of vigorous tamping with the tip of the abdomen. When the entrance is closed she suddenly flies away without inspecting her work.

The larvae of *Rubrica* are fed on adult flies of large or medium size. A variety of species are caught, depending, no doubt, upon availability. The most usual kinds brought in, however, by individuals kept under observation were the Syrphid, *Volucella obesa* Fabr. and TABANIDAE including *Tabanus occidentalis* L. The adult goes on feeding the larva as the latter grows. The larva lies in the chamber at the end of the burrow curved into a shape resembling a capital " J," the head being bent round on to the underside of the thoracic segments. In the angle thus formed the fly, which is supplied to the larva in a paralysed condition, is clasped while it is being consumed. A full-grown *Rubrica* larva was observed to finish up a whole individual of *Volucella* in a single afternoon, every part being eaten except for fragments of the legs, wings and hard exoskeleton. The larva pupates within a silken cocoon.

In view of the fact that *Rubrica* is such an energetic hunter of Diptera, it is

of interest to note that the fly *Pachygraphomyia spinosa* Malloch is a constant attendant of the wasp. These flies hang around the vicinity of the nesting holes and they are presumably parasitic, although this has not been proved by observation. The fly has, however, been seen to enter the freshly opened burrow of the wasp, but in the case observed its exit was precipitated because the parent wasp chased it out. It was noted above that the wasp is careful to close the burrow containing a young grub whenever she goes away but is negligent about this precaution when the larva is nearly full grown. It may be significant, therefore, to note that *Pachygraphomyia* will enter burrows opened up by a returning wasp but takes no notice of burrows containing a full-grown larva which are left open while the wasp is away.

Pachygraphomyia is an extremely alert fly and thus may be able to take care of itself even though living so close to a potential predator. However, *Rubrica* has never been seen to take any interest in this fly except when it actually enters a burrow and it seems that the explanation suggested by Dr. O. W. Richards, who determined the species, is the correct one. He suggested that the hunting reflex of *Rubrica* is not active in the immediate neighbourhood of the nesting site, hence so long as *Pachygraphomyia* keeps sufficiently close to the centre of activity round the nesting holes it is safe.

Liohippelates pusio (Loew) is another Dipteron associated with the *Rubrica* colonies. In the case of this species its small size causes it to be beneath the notice of the wasp. The fly has often been seen entering and leaving the open burrows of the wasp. The exact rôle of this species has not been elucidated but it is presumed that small larvae of a Dipteron which are frequently seen feeding in the debris composed of excreta and fragments of prey, which collects in the brood chamber, are the larvae of this species.

The distribution of *Rubrica* in Trinidad is indicated by the following locality records : TRINIDAD : Northern Range, Mt. St. Benedict, 8.iii.33 ; Mt. Tabor, 10.xi.31 ; East Coast, Balandra Bay, 19.vii.33 ; St. Bernard, Mayaro, 29.xii.34 ; Central districts, O'Meara Savannah, 30.iv.32 ; Hart Trace, Plum Road, 10.i.35 ; Southern districts, Erin Savannah, 24.i.35.

Bicyrtes discisa (Tasch).

This is another common species in Trinidad which nests in similar situations to those favoured by *Rubrica*. A particularly likely place to find a colony of *Bicyrtes* is in the area of hot dry sand at the top of a beach beyond the reach of the highest tides. The burrows of this species descend into the ground at a steep angle for some 12 cm. The female wasp catches nymphs of Heteroptera including PENTATOMIDAE. The victim is carried into the burrow, and the egg is laid plastered along the proboscis.

The distribution of this species in Trinidad is indicated by the following collecting records : TRINIDAD : Northern Range, Mt. St. Benedict, 17.xi.34 ; Mt. Tabor, 24.i.32 ; St. Michaels Valley, 6.iv.33 ; Eastern districts, Pt. Radix, 8.iv.33 & 4.iii.35 ; Nariva, 10.iii.35 ; South Coast, Guayaguayare, 25.xi.34 & 20.i.35.

Stizus cingulatus Sm.

The present species also nests in similar sites, often sharing an area with *Rubrica* and very frequently colonising the beach edge above high-water mark. The adult wasps have been known to catch Homoptera.

Specimens from : TRINIDAD : Northern Range, Gasparillo **Road, 28.x.34**; Maracas Bay, 1.x.33.

Microbembex monodonta (Say).

Microbembex has invariably been found nesting near the seaside, either in sandy flats at the mouths of rivers or in the dry sand above high-water mark. The burrows descend for some 8 inches below the surface, often reaching a zone of slight moisture. By contrast to all the above-noted species, which show a certain conservative tendency in the matter of their prey, the present species is extremely catholic in this respect. A great variety of small winged insects have been found in the burrows, small winged ants and, when available, winged termites being among the most frequently captured prey.

Specimens from : TRINIDAD : North Coast, Maracas Bay, 28.x.34; Salybia Bay, 19.v.35; South Coast, Guayaguayare, 25.xi.34 & 20.i.35; Erin River mouth, 23.i.35.

Acknowledgements.

I am indebted to Prof. J. B. Parker, The Catholic University of America, for determining the wasps mentioned in these notes.

BOOK NOTICE.

The Butterflies of the Niagara Frontier Region. By W. WILD. (*Bull. Buffalo Soc. nat. Sci.* **19** : 1–55, 8 pls.) 1939.

This work deals with the Rhopalocera of the area within a radius of some 50 miles of Buffalo, and the systematic arrangement adopted is that of Dr. McDunnough's 1938 Check List.

The four divisions of the work are the introduction; collecting, rearing and preserving of butterflies and moths; what are butterflies; and the butterflies of the Niagara Frontier Region. A check list of the species is given and there is a Bibliography and an Index.

There is much information of use to a beginner.

THE BLACK FORM OF *CICINDELA CAMPESTRIS* L. var. *FUNEBRIS* STURM. (COLEOPT.)

By Dr. K. G. BLAIR, F.R.E.S.

THE specimen of *C. campestris* var. *funebris* was taken by Mr. E. Taylor on Dunkery Beacon, Somerset, on 22nd Aug. 1939. The only other British record of this form that can be traced is that of the specimen taken by the late Dr. T. A. Chapman in Glen Finnart in Oct. 1858 (1867, *Ent. mon. Mag.* **3** : 251). On this record is probably based Fowler's " Clyde district of Scotland (Loch Long, &c.)." In Dr. Sharp's collection is a specimen from the New Forest, June 1910, that matches Mr. Taylor's specimen very closely, both being dull black above with the usual yellow spots rather indistinct, in both the underside shows quite strong purplish colours. These records seem to indicate that the form may occur anywhere with the type and is not a mountain race.

The cause of this black coloration is obscure—it is definitely not due to grease—but is probably some structural defect in the formation of the fine laminae to which the normal metallic colouring is due.

It is known that the insect undergoes some change in colour during life, freshly emerged specimens being of a brighter green than those that have been out some time, a change due apparently to continued exposure to sunlight, and it is possible (though scarcely probable) that the dark green dull-coloured form sometimes found (var. *nigrescens* Heer, 1838) is but a sign of old age. The var. *funebris*, however, can scarcely be a form of extreme senility, or intermediate stages would be more frequent.

A somewhat parallel instance of age variation in colour, with a sudden black aberration, is afforded by *Cetonia aurata* L. and its var. *nigra* Gaut., though the black form in this case is confined in this country to the Scilly Islands.

COLEOPHORA OTITAE ZELLER, NEW TO BRITAIN (LEP.)

By H. M. EDELSTEN, F.R.E.S.

THE larval cases of *C. otitae* were found in South-east Kent in June 1939. The larvae make white blisters on the leaves of *Silene nutans*. The imago appears in August and September. Larval cases of *C. nutantella* are to be found on the seed capsules of *Silene inflata* from August until the spring. The case is very much shorter than that of *C. otitae*. The imago appears in June.

I am indebted to Mr. H. D. Stringer for identifying *C. otitae* and to Mr. L. J. Ford for lending specimens of *C. nutantella* for exhibition.

A GYNANDROMORPH SPECIMEN OF *ANACRIDIUM MOESTUM* (SERV.) ORTHOPTERA, ACRIDIDAE

By Edith POTTER, Ph.D., D.I.C., F.R.E.S.

(Rothamsted Experimental Station.)

INTRODUCTION.

A GYNANDROMORPH of *Anacridium moestum* (Serv.), discovered by Dr. M. A. Volkonsky, Institut Pasteur of Algiers, amongst material bred in cages, was sent to me by Dr. B. P. Uvarov of the Imperial Institute of Entomology, for study.[1]

The gynandromorph had been killed and fixed in Bouin's fluid; this was necessary, but made the finer dissection of the internal organs difficult as they were rendered very brittle.

This paper is a description of the external characters of the gynandromorph, the internal anatomy of the genital organs and a comparison with the normal male and female of the same species.

The terms used in this description are those employed by Dr. R. E. Snodgrass in his papers on grasshoppers and in his textbook *The Principles of Insect Morphology.*

I have to thank Dr. Volkonsky and Dr. Uvarov for giving me the opportunity of studying this unique insect, and Dr. Tattersfield for allowing me the facilities of his laboratory.
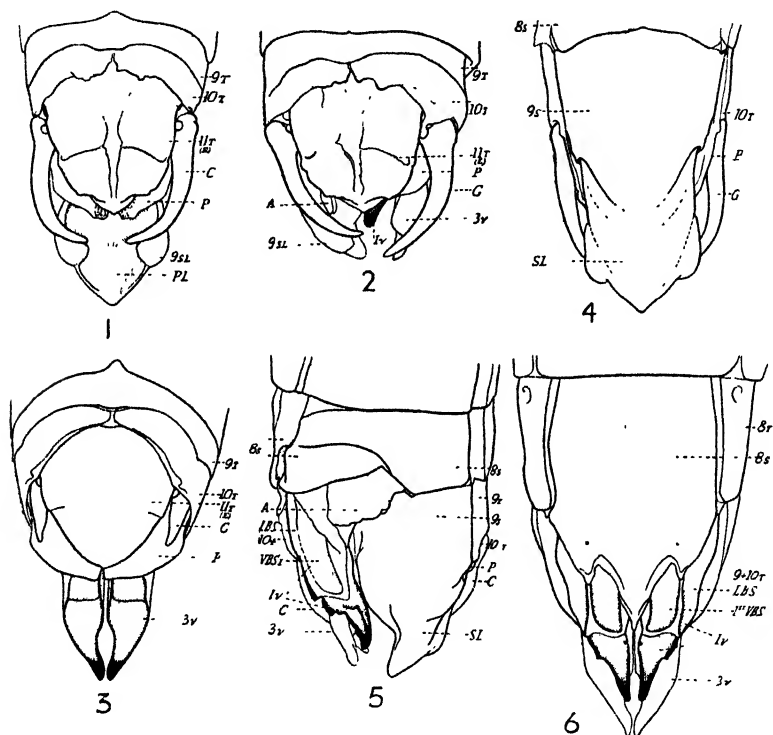
EXTERNAL CHARACTERS.

The normal male and female *Anacridium moestum* are similar to each other in general external structure, but the cerci and eleventh tergite show distinct sexual dimorphism. The cerci of the male are long and sickle-shaped, but those of the female are small and peg-like (figs. 1 and 3, C). The eleventh tergite of the male is sculptured, that of the female is smooth (figs. 1 and 3, 11 T). It is in the character of these organs and the genitalia that the interest of the gynandromorph lies.

[1] Gynandromorphism in ACRIDIDAE appears to be rare. Hebard (1919, *Trans. Amer. ent. Soc.* **45** : 268, footnote) reported a specimen of *Oëdaleonotus phryneicus* Heb. with the left side of a male and the right of a female, but no description even of the external morphology was given. Carothers (1939, *Genetics* **24** : 97) recorded a complete gynandromorph produced as a hybrid between *Trimerotropis citrina* Scudd. ♂ × *T. maritima* Harr. ♀, which had the left side externally of a male, but no sign of internal reproductive organs of that sex; the right side was that of a female externally and had a normally developed ovary. Natori (1931, *Trans. Sapporo nat. Hist. Soc.* **12** : 1–5) gave a detailed description of a larva of *Podisma sapporense* Shiraki, with the external genitalia of a male but a testis, of normal size, with a mass of ovarian tissue attached to it; spermatogenesis in the testis was accomplished normally, but in the ovary part of the ovo-testis the eggs were immature. Thus, no gynandromorph that would be complete both externally and internally is yet recorded in ACRIDIDAE, and the case described by Mrs. Potter is no exception.—B. P. UVAROV.

The modifications of this gynandromorph first appear dorsally in the eleventh tergite and ventrally in the eighth sternite. Although some irregularities of shape and changes in proportion occur in the eleventh tergite of the gynandromorph (fig. 2, 11 T), the insect is dorsally a slightly misshapen male with no typically female characters. It has the usual male cerci and the sculptured tergite of the normal male.

The eighth sternum of the normal male is narrow (fig. 4), that of the female is wide and is produced into a median lobe or egg guide (fig. 6). The

FIGS. 1–6.—Dorsal view of terminal segments of: 1, male abdomen; 2, gynandromorph; 3, female abdomen; ventral view of terminal segments of: 4, male abdomen; 5, gynandromorph; 6, female abdomen.

eighth sternite of the gynandromorph is male on the right side, but at the mid-line it narrows and is deeply folded laterally. This narrowing and folding is probably due to wounding, as a large lump of indeterminate tissue is attached to its distal margin and overlies the genitalia (fig. 5, 8 S).

The male ninth sternum is present on the right side (*ventral view*) (fig. 5, 9 S), but is shorter than in the normal male; the subgenital plate (fig. 5, SL) is considerably shortened and only the right side of it is developed.

On the left side and partially overlaid by the amorphous tissue of the eighth sternum lies the first valvula of the female genitalia (fig. 5, 1 V) slightly distorted and curving outward instead of inward (cp. fig. 6, 1 V). The lateral

and first ventral basivalvular sclerites are present (LBS, VBS). The latter are larger and more prominent than in a normal female. The dorsal or third valvula is present, but dorsally its structure bears some resemblance to the dorsal part of the subgenital plate of the male; ventrally it has the straight edge of the normal third valvula, but its apex is not upturned. It is not strongly cuticularised (fig. 8, 3 V). A small lobe, the second valvula, which is membranously connected with the third, is present (figs. 11, 14, 2 V).

The left half of the ninth sternum and subgenital plate of the gynandromorph are not so deep and pouchlike as that of the normal male (cp. figs. 9 and 10).

From the above description it can be seen that this gynandromorph tends

FIGS. 7–10.—Right lateral view of end of: 7, female abdomen; 8, gynandromorph abdomen; left lateral view of end of: 9, male abdomen; 10, gynandromorph abdomen.

externally to be more male than female. Dorsally it is male, ventrally it is half male and half female.

INTERNAL GENITALIA.

The gynandromorph is male internally as far back as the distal part of segment seven, where the right side takes on female characters, the left side remaining male.

The apparently normal testes lie in the fourth, fifth and part of the sixth segments, dorsal to the gut, as in the normal male (fig. 12, TS). The testes are applied to each other and have a common supporting filament (F). From the left testis a vas deferens (VD) passes posteriorly beside the gut to enter

the ductus ejaculatorius (DE) at the base of the left accessory gland (LAC). The latter consists of a mass of small tubules entering the left branch of the ductus. The accessory gland of the right side is present (RAC), but lies more towards the left side of the animal than is usual. The two short branches of the ductus unite and the common ejaculatory duct passes over to the left side of the insect and enters the subgenital lobe (SL). The ductus of the normal male passes into the ejaculatory sac, which is contained in the endophallus (fig. 13, B). Only a trace of the right vas deferens was seen.
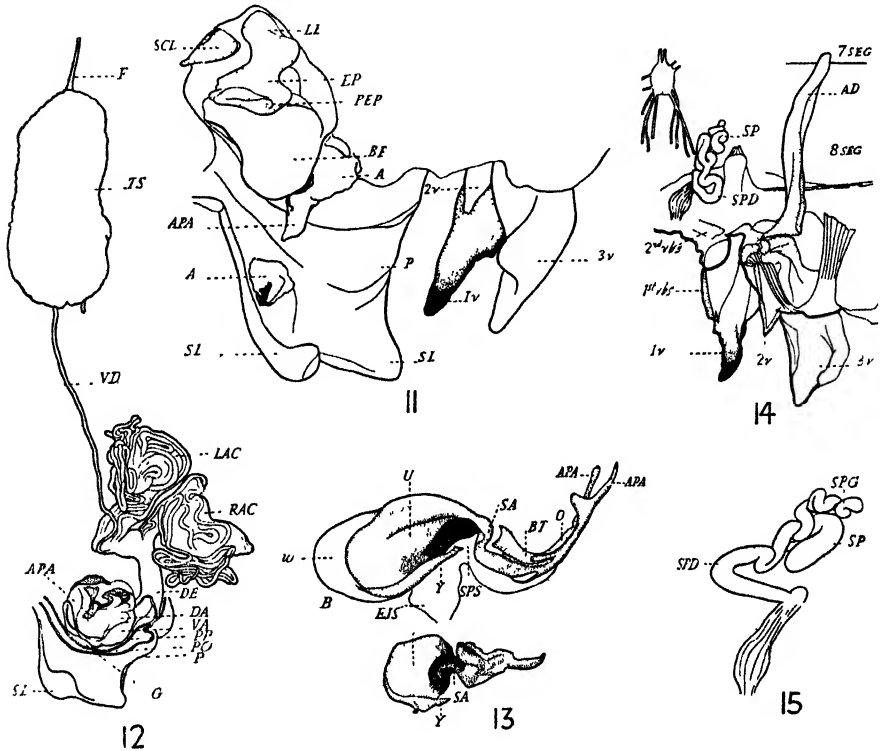
FIGS. 11–15.—11, Male and female genitalia of gynandromorph; 12, male genitalia of gynandromorph; 13, endophallus of (A) male genitalia of gynandromorph and (B) normal male, left side; 14, female genitalia of gynandromorph, spread out; 15, spermatheca of gynandromorph.

When the epiproct (11 T) was removed and the podical plates (P) were slit and spread apart it could be seen that the left sclerite, giving insertion to the retractor muscles, is present (fig. 11, SCL) and also part of the epiphallus, the lateral lobe (fig. 11, LE) and the posterior process (PEP). The bridge of the epiphallus is not present, since only the left half of the subgenital lobe is developed (SL).

Distal to the posterior process of the epiphallus is a membranous fold, which probably represents the left half of the basal fold (BF), lying against

the folded pallium (P). Below the basal fold protrudes a triangular cuticularised process, probably an apical process of the aedeagus (APA).

The much-modified male genitalia were exposed by removing the pallium and slitting the basal fold. The genitalia are so much reduced and distorted that the homologies given here can only be tentative. The ejaculatory duct (fig. 12, DE) enters the subgenital lobe at its extreme inner margin and appears to open directly into the genital cavity (G). Arising from the floor of the genital cavity is a globular structure which seems to consist ventrally of the left part of the ventral lobe (VA) and dorsally of the dorsal lobe of the aedeagus (DA). Projecting from the apex of the dorsal lobe is a sclerite which appears to represent one of the ventral apical processes of the aedeagus (APA). Dorsally the dorsal lobe is incomplete and the homologies of the dorsal cuticularised structure could not be determined. Neither the dorsal nor the ventral lobe is complete, and no phallotreme cleft could be seen on the dorsal lobe, only half of which is presumably present.

The endophallus or " sperm ejection pump " (Snodgrass 1935a) consists only of the left side with its muscles and is much reduced in size and distorted. Fig. 13 shows the endophallus of the gynandromorph A compared with the left view of that of a normal insect B, dissected out and freed from muscle. As the gynandromorph endophallus is incomplete and the ductus opens directly into the genital cavity, it would seem that the male part of the genital organs are unlikely to be functional. Even though the sperms were normal, there is no mechanism for inserting them into the female.

No trace of ovaries or common oviduct could be found. The right apodeme of the genitalia, arising between the bases of the third and first valvulae, is present and extends into the distal part of the seventh segment (fig. 14, AD) as in a normal female. The cavity or pouch found in the female between the eighth sternite and the external genitalia is absent.

Slightly to one side of the mid line, in the eighth segment, lies a spermatheca and its gland (SP and SPG), similar in external structure to that of a normal female. The spermathecal duct appears to open into the side of a short blind tube, which terminates above the indeterminate or wound tissue at the base of the first valvula (1 V) and the posterior margin of the eighth sternite.

The second ventral basivalvular sclerite of the first valvula is vestigial (second VBS). In the normal insect it forms half the bow protecting the opening of the spermathecal duct. In the gynandromorph only its outer apex is present.

CONCLUSIONS.

The gynandromorph of *Anacridium moestum* is not complete, but is more male than female. Externally, it is male dorsally; but is half male, half female on the ventral side.

Internally, the insect is also more male than female. It possesses part of all the male organs, but only the spermatheca of the female.

It is not possible, without cytological examination, to know whether normal sperms were produced. Even though they were produced there is no mechanism for conveying them to the female and it is probable that the insect was functionally sterile, although it may have produced fertile sperms.

The cause of the production of the amorphous tissue is unknown.

REFERENCES.

SNODGRASS, R. E., 1935, The abdominal mechanisms of a grasshopper.   *Smithson. misc. Coll.,* **94** (6).

——, 1935a, *Principles of Insect Morphology.*

ABBREVIATIONS.

A	Amorphous tissue.	RAC	Right accessory gland.
AD	Apodeme.	S	Sternite.
APA	Apical process of aedeagus.	SA	Arm of posterior phallotreme sclerite.
BF	Basal fold.	SCR	Sclerite giving insertion to retractor muscles.
BT	Bridge of anterior phallotreme sclerites.	SEG	Segment.
C	Cercus.	SL	Subgenital lobe of ninth sternum.
DA	Dorsal lobe of aedeagus.	SP	Spermatheca.
DE	Ductus ejaculatorius.	SPD	Spermathecal duct.
E	Epiproct.	SPG	Spermathecal gland.
EJS	Ejaculatory sac.	SPS	Spermatophore sac.
EP	Epiphallus.	T	Tergite.
F	Supporting filament.	TS	Testes.
G	Genital chamber.	U	Lateral plate of endophallus.
LAC	Left accessory gland.	1 V	First or ventral valvula.
LBS	Lateral basivalvular sclerite.	2 V	Second or inner valvula.
LEP	Lateral lobe of epiphallus.	3 V	Third or dorsal valvula.
O	Anterior (dorsal) lateral sclerite of phallotreme cleft.	VA	Ventral lobe of aedeagus.
		VBS	Ventral basivalvular sclerite.
P	Paraproct (podical plate).	VD	Vas deferens.
PEP	Posterior process of epiphallus.	W	Anterior apodeme of endophallic plate.
PL	Pallium.		
PO	Cut edge of outer wall of pallium.	Y	Gonopore process of endophallic plate.
PP	Cut edge of inner wall of pallium.		

BOOK NOTICE.

Adaptive coloration in Animals. By H. B. COTT with an introduction by J. S. HUXLEY. 8vo. London (Methuen) (1940). pp. xxxii + 508, 1 pl. col., 48 pls., 84 figs. Price £2.

This book is an attempt at a comprehensive treatment of the nature and meaning of coloration in the animal world. The first part deals with concealment either to escape enemies or to capture prey, the second with advertisement whether for warning or alluring and the third with disguise—with animals that imitate other animals or their own environment. Many of the illustrations are from original photographs made by the author, who is an expert photographer, and all the text illustrations are from originals by the author. There is a bibliography of nearly 700 titles, and indices are provided to scientific names, authors' names and to subjects.

In the Introduction is the following statement : " . . . by applying optical and psychological principles, he [the author] has pushed the analysis of visual allaesthetic characters to a new level, and shown that many of them constitute adaptations of a quite unsuspected degree of refinement. Far from genetics in any way throwing doubt on their adaptive interpretation, the facts of cryptic, warning and mimetic coloration pose searching questions to the geneticist, and demand a recasting of many current views on the efficacy and mechanism of selection."

BOOK NOTICE.

La Faune de la France en tableaux synoptiques illustrés. Tome 7 : Hyménoptères. Par L. BERLAND. 8vo. Paris (Delagrave). 213 pp., 712 figs.

This volume completes the series of illustrated volumes on the Fauna of France commenced in 1923.

It opens with a short introduction, which is immediately succeeded by the main body of the work arranged in keys.

The aim of the work is not to provide the specialist with a means of identifying the species of Hymenoptera of France but rather to assist the non-specialist to obtain some idea as to the identity of his specimens at least so far as the genus to which a given insect belongs.

The very large number of species concerned, possibly 10,000 in France, prevents an attempt at specific keys for all the Hymenoptera of France without producing a very much larger volume.

The many figures consist of outline drawings of the whole insect with details of the parts necessary for identification; they are in the main original, and made from nature. The book is of a size which permits its easy transport in the pocket.

BOOK NOTICE.

A Text-book of Zoology. By T. J. PARKER and W. A. HASWELL. 6th edition
in 2 volumes, revised by O. LOWENSTEIN. Vol. 1, pp. xxxii + 770, 733
figs. 8vo. London (Macmillan), 1940. Price 36*s.*

The first volume of the 6th edition of this famous text-book has appeared
and it is revised by Dr. Lowenstein of the University of Glasgow. The reviser
has aimed at retaining the fundamental character of the book, which attempts
an inductive treatment of the subject matter, based on detailed type descriptions
to which in every case are added an account of the classification and an extensive
comparative account of the general organisation of the members of the group.

The hypothetic phyla of the original work are now abandoned in favour of
those generally adopted in modern Zoology.

This volume contains the introductory matter and that part of the general
work relating to the invertebrates proceeding from the Protozoa and extending
so far as the Echinodermata including the Arthropoda.

The Arthropoda comprise pages 385 to 536.

BOOK NOTICE.

Studies in the Mecoptera. Biology and Morphology of some North American
BITTACIDAE. By L. R. SETTY. The genital anatomy and mating be-
havior of *Boreus brumalis* Fitch. By K. W. COOPER. *Amer. Midland
Nat.* 23 : 257–367, text illust. 1940.

The first of the two papers here to be noticed is much longer than the second
and extends to nearly 100 pages.

It is written as the result of first-hand study of the living insects of several
species of *Bittacus*. The study was pursued both in the field and in the
laboratory.

The full life-history of several species is described in detail as is the morpho-
logy and the internal anatomy.

The second and shorter paper is concerned only with a single species and
gives a detailed account of the genitalia of the male and female and describes
the mating behaviour and act of copulation. All the dissections for this work
were made from living specimens.

THE FIRST ENTOMOLOGICAL SOCIETIES. AN EARLY CHAPTER IN ENTOMOLOGICAL HISTORY IN ENGLAND

By Francis J. Griffin.

(Registrar, Royal Entomological Society of London.)

The history of Entomology in this country has still to be written, but it is perhaps not out of place to put on record the story of the activities of the British entomologists who made the first attempts to found societies for the organised study of our science in Great Britain, all the more so because there have recently come into the possession of the Royal Entomological Society of London various manuscripts which add considerably to our knowledge of these activities. I take this early opportunity of thanking Mr. N. D. Riley and Mr. A. Cockburn Townsend, both of the British Museum, who have read this paper in manuscript and suggested modifications which I have gladly incorporated in the paper.

For the origins of Entomology, one must seek much farther back in history than is required by my present purpose, but modern entomology may perhaps be considered to date from 1758, when Linnaeus published the 10th edition of his *Systema Naturae*, now universally regarded as the starting-point, at least so far as concerns nomenclature, the key to any organised biological science.

It will naturally be understood that this starting-point was not the sudden result of a spontaneous effort on the part of Linnaeus or of any of his contemporaries and in point of fact the actual year is no more than a matter of convenience, chosen because the 10th edition happened to be published then.

So far as I am aware, there is no record of any attempt at the formation of an Entomological Society anywhere in the world earlier than that which I shall presently mention, and it is a matter of particular interest to our society that apparently almost a century elapsed between the first attempts, all of which took place in London, and those of our continental colleagues.

I. The [first] Aurelian Society [1742–1748].

To this Society Benjamin Wilkes (1742) dedicated his work entitled " Twelve new designs of English Butterflies " in 1742, as follows : " Dedication to the worthy Members of the Aurelian Society."

In his " Review of the rise and progress of the science of Entomology in Great Britain " Haworth (1807) said of Wilkes' book : " The author informs Ladies and Gentlemen, that they may inspect the original Insects, from whence these ingenious designs were taken, in his own collection in Fleet Street; which we believe is still in existence, and in the possession of the Linnean Society of London; arranged somewhat after the manner of the above-mentioned plates."

The next reference to this Aurelian Society is by Moses Harris (1766), who chose to preserve some of the details regarding the Society by the same method as Wilkes. In the Preface to his *Aurelian* published in 1766 he said : " It is now above twenty years since I first began to collect and pursue the study of Insects; the first hint I received was from Mr. Moses Harris, an Uncle of mine, who was then a member of the old Society of Aurelians [*i.e.*, the one now under discussion], which was held at the Swan Tavern in Change-Alley : I was then too young to be admitted a member, tho' the strong inclination I had to be searching into this part of Natural History, made me very desirous : I was then but twelve years old, so obliged to defer it, till age should ripen and furnish

me with sufficient sagacity, whereby I might become fitting for the company of that ingenious and curious body of people. I was, however, deprived of that pleasure, for not long after the great Fire happened in Cornhill, in which the Swan Tavern was burnt down, together with the Society's valuable collection of insects, books &c. and all their regalia : The Society was then sitting, yet so sudden and rapid was the impetuous course of the fire, that the flames beat against the windows, before they could well get out of the room, many of them leaving their hats and canes; their loss so much disheartened them, that altho' they several times met for that purpose, they never could collect so many together, as would be sufficient to form a Society, so that for fourteen years, and upward, there was no meeting of that sort, till Phoenix-like our present Society arose out of the ashes of the old."

The fire which brought the Society to an end occurred on 25 March, 1748 (Neave & Griffin, 1933). Thus the [first] Aurelian Society was in existence at least from 1742 to 1748.

It would be of great interest to know what constituted the " regalia " referred to, and to know what was contained in the collection and library, but no further information is recorded so far as I know.

The name Aurelian was formerly given to " a collector and breeder of insects, especially of butterflies and moths; a lepidopterist " according to the *Oxford English Dictionary*. Its origin is given as the word " *Aurelia* from the Latin *aurum* = gold, thus synonymous with a chrysalis." It was used by Topsell in 1607 for the pupa of an insect, especially of a butterfly. Perhaps the most recent usage was by the late Prof. Selwyn Image, whose portrait, with that of the late Dr. T. Longstaff, was exhibited in the Royal Academy of 1909 under the title of " The Aurelians." The portrait is now in the keeping of the Royal Entomological Society of London, to whom it was presented by Mrs. Image. It is painted by I. Cooke.

II. The [second] Aurelian Society [1762–1766].

For their second attempt the London Entomologists chose the same name and another AURELIAN SOCIETY was founded in London in 1762, according to Hagen (1863).

As stated already (above), Harris (1766) has recorded certain information regarding this Society. On the title-page to his work he described himself as " Secretary to the Aurelian Society " and the book is dedicated thus : " Dedication to the President, and the rest of the gentlemen, the worthy members of the Aurelian Society."

In the Library of the Royal Entomological Society of London is a copy of the *Aurelian* with the year 1778 added to the title-page. On this copy Harris is still described as " Secretary to the Aurelian Society " although this description is missing from the title-page of his *The English Lepidoptera : or the Aurelians pocket companion* which appeared in 1775. Since Harris was his own publisher, this requires explanation which, fortunately, is available. I find on examination that the title-page to the later " edition " of the *Aurelian* is identical with that of the earlier edition but that added at the foot is the later date and the name of J. Robson of New Bond Street. It is clear that Robson obtained a stock of the title-pages and caused his name and the date to be overprinted thereon before he issued more copies of the book.

I have traced no further information regarding this Aurelian Society and cannot find that it continued after 1766.

Haworth (1807) wrote of Harris : " It is moreover said of Moses Harris, that

he was one of the very first who endeavoured to form ' A Society of Aurelians ' in this country, for the purpose of recording and diffusing the knowledge he had acquired; of which, however, nothing further need be mentioned in this place, as it will be much more appropriately treated of by our able Secretary [J. Surr] in a paper on the ' History and Intentions of the Entomological Society,' [1] which he is preparing to request the Society's acceptance of :—and which, should public approbation encourage it, will be succeeded by a series of papers from my own pen, concisely explaining the contents of the Entomological Cabinet."

I think it probable that Haworth was either unaware that there were two Moses Harris, as is obvious from the remarks of Harris the younger (1766), or else, as is less likely, he was unaware that there were two Aurelian Societies.

Surr's (1812) paper, referred to by Haworth, was published after several delays, and probably in very abbreviated form, in 1812. Since it more closely concerns the affairs of a later society, it is fully dealt with on p. 57.

III. The Society of Entomologists of London [1780–1782].

For their third attempt at the formation of a Society the London Entomologists temporarily discarded their attachment to the name Aurelian and the next Society recorded is The Society of Entomologists of London, of which several records exist. These appear to emanate all from the same source, which I am happy to have traced in some original contemporary documents.

Newman (1835) records that the Society was established in 1780 and continued to the first week in August 1782 : he referred to Haworth as the source of his information. Haworth's information is found recorded in the minute book of the [third] Aurelian Society and [first] Entomological Society of London, which is now in the care of the Royal Entomological Society of London. On page 28 of this book is this :—

" 10. The President [Haworth], shewed the Members a MSS. book being the Original Minute Book, and containing the Laws, of a Society of Entomologists, long since existing in London - it is dated the first week in May 1780." The book was exhibited to the Society at the meeting of the [third] Aurelian Society held at Haworth's house in Little Chelsea " near London " on 14 January, 1805, and at the end of the minutes, also in Haworth's handwriting, is the following : " Mem. The President [Haworth], who acted as Secretary, having thought proper, to extract much valuable information from the Minute book alluded to in Section 8 [recte 10] on the preceding page; it was thought advisable in order to preserve it, to copy it in here.

" The following is a copy of the Laws of the said Society, to which are subjoined, the names of the Members.

" We who have hereunto subscribed, do hereby promise, each for himself, that we will endeavour to promote the good of the Society of Entomologists of London, for the study of insects, and to pursue the end for which the same was founded. That we will be present at the meetings of the Society as often as we conveniently can especially at the Anniversary elections; and upon extraordinary occasions : and that we will observe and abide by, the Statutes and orders of the said Society; provided we have liberty to withdraw ourselves from the Society, when we think proper, by signifying such our intention to the president of the Society for the time being by Letter.

(Signed)

1. D. Drury.   Wm. Honey.   John Swift.   John Francillon.
5. Ralph Tinley.   Wm. Jones.   Joseph Bentley.

[1] This is the first " Entomological Society of London," see p. 61.

" The above mentioned Society as far as can be collected from their Minute Book did not last longer than the first week in August 1782, but three of the Members are still living [1805], viz. Messrs Honey, Francillon and Jones.— Tinley's Cabinet is now in the possession of Sir Jno. St Auban and contains a few Unique Moths—Bentley's collection was sold by his widow for 50 Guineas to Mr Heaviside the Surgeon : it contained 926 Lepidoptera, in the highest preservation, and was also rich in Coleoptera."

The above is followed in the minute book, referred to above, by some extracts from the " minute book " of the Society of Entomologists' of London which deal only with the occurrence and capture of Lepidoptera.

In 1937 the Royal Entomological Society of London was enabled to acquire by purchase a MSS. entitled : " Catalogue of John Francillon's Cabinet of Insects and other Memorandums. A Copy of Articles belonging to an Aurelian Society. A.D. 1780." The " Aurelian Society " referred to is in fact The Society of Entomologists of London, for on page 63 is a " Copy of Articles belonging to an Aurelian Society " and the " Articles " which follow are the same, but for a very few, quite minor, grammatical changes, as those quoted above from Haworth. The list of names given is, however, somewhat longer and comprises : " Dru Drury, President; Willm Honey; John Swift; John Francillon; Ralph Tinley; Willm Jones; Joseph Bently [sic]; . . . Beckworth [2]; . . . Smith; . . . Pickersgill."

The " Articles " are followed by the " minutes," which in fact are no more than a weekly calendar of Entomological matters from the first week in May 1780 to the first week in August in 1782.

From its appearance, and an occasional mis-spelling such as " Entomoligical ", the book seems to me to be a " fair copy " made by a contemporary scribe for the use of Francillon. It is a manuscript written in a beautifully clear hand and the book is bound in a full sheepskin binding. The book has obviously been well cared for and shows none of the usual signs of age so often to be found in a book already well over a century and a half old.

It is apparent that the individual members of the Society were much interested in its doings, for still another contemporary record is in existence. In 1933 Sir Edward Poulton exhibited to the Royal Entomological Society of London (Poulton, 1933) a manuscript Diary and rough draft of the Proceedings of the Society and certain manuscript notes all once the property of William Jones, already noted as one of the members, which manuscripts had been presented to the University of Oxford by Dr. F. Dawtrey Drewitt, a descendant of Jones.

The rough draft of the Proceedings records the elections of members; modifications of rules; and weekly lists of insects bred, seen or captured. The " Diary " also contains a copy of the " Articles " already quoted and this is the third copy now known to exist. From Sir Edward's account it is learned that Drury was the President, Honey the Vice-President, Jones the Secretary, Swift the Assistant Secretary. It is also stated that Jones resigned his membership from June 1781 to April 1782, during which time the Society met on Sundays. It is known that Jones was a Swedenborgian and this may account for his action. Jones' decision is given on the authority of Dr. Drewitt, but Sir Edward cannot confirm the day of meeting as being Sunday during the period mentioned and suggested that the " Meetings " referred to were in fact collecting expeditions. From the extracts given by Poulton it appears that in 1781 the following Officers were elected : Drury, President; Tinley, Vice-

[2] It is probable that this is an error and Beckwith is intended, see p. 53.

President; Swift, Secretary; and Beckwith, Assistant Secretary. These Officers were all re-elected in 1782.

It is stated by Poulton, from the records he is quoting, that in November 1781 the Society decided to remove from its " present Place of Meeting," unfortunately not specified, " to the Bank Eating House in Throgmorton Street." In the following January it was decided that the Society should meet twice a month from March to September inclusive " as usual viz. the Second & Last Tuesdays in the Mo." and from the end of September to the beginning of March only once " viz the Secd. Tuesday in the Month."

As regards the subscription payable by the members, the only information I have found is that it was decided in January 1782 that while the society was meeting only once a month the fine for absence should be one shilling per meeting, and at a later undated meeting in 1782 it was " resolved unanimously that in future this Society do meet only on the second Tuesday in every Month & that one Shilling be then spent by every present Member & the Fine for absence be likewise one Shilling."

It should be remembered that the real value of a shilling in 1780 was considerably more than nowadays and it is probable that the levy of a shilling from every member, whether he be present or not, was required to pay the cost of hiring the meeting room.

The list of members which I have extracted from these records is :—

D. Drury,
Wm. Honey,
John Swift,
John Francillon,
Ralph Tinley,
Wm. Jones,
Joseph Bentley,

John Church, Islington, Surgeon,
Thomas Pickersgill, Wte Lyon Street, Norton falgate,
John Beckwith, Lant Street, Southwark,
—Smith.

The disappearance of the Society of Entomologists of London marks the end of the first period in the history of the early Entomological Societies. The first attempts, which are recorded above, were obviously directed by a small band of enthusiastic collectors and it is unlikely that the total membership of any Society much exceeded half a dozen members at a given time. Certainly the day of the big Entomological Society as it is now understood had not yet dawned nor was the dawn in prospect.

What may be considered the second period opened with the commencement of the nineteenth century. It is a period when practically the whole initiative in the association of London Entomologists was due to one man, namely Adrian Hardy Haworth, born 1767, died 1833.

Haworth was a really remarkable man; his entomological work is still consulted and he wrote several important Botanical works. His collection of insects must have been extremely complete for the period and his library equally so. Some of his books were bought after his death and are now in the Library of the Royal Entomological Society of London. He was quite certainly a wholehearted lover of insects and an idealist who spent much energy and time on the formation of a complete collection of native insects. I think it is probable that his anxious wish to form a really complete collection of British Lepidoptera influenced his attempts at the formation of a successful Entomological Society.

IV. The [third] Aurelian Society [1801–1805].

The fourth attempt at the formation of a Society was that made by Haworth in 1801, which resulted in the [third] Aurelian Society, the last Society to use this pretty but now old-fashioned name.

A copy of the minutes of this Society is now in the care of the Royal Entomological Society of London and I give here some details concerning the volume in which it is written.

The volume is an ordinary writing-book such as was used commonly in the early nineteenth century and on the fly-leaf is written : " This book, which was for many years in the possession of Dr John Edward Gray of the British Museum and by him given to Mr Frederick Smith, was presented by the latter to the Entomological Society of London on the 4th day of November 1872.

[signed] Edward W. Janson.

Libn. Entom. Soc. Lond."

In the main the book is in Haworth's handwriting and it contains a copy of the proceedings of the [third] Aurelian Society from July 1801 to January 1805; the minutes of the [first] Entomological Society of London from May 1806 to 1822; a notice of a " Meeting of Gentlemen desirous of promoting the study of Entomology held . . . on June 25. 1822."; and a " List of papers in possession of the Secretary of the Entomological Society of London . . . January 4th. 1809."

The description of J. E. Gray as the Secretary in the list of those present at the meetings from May to July 1822, the last in the book, explains his custody of the volume. Frederick Smith was sometime President of the present Royal Entomological Society of London.

The book opens with some " Preliminary Remarks " stating that it was thought desirable to preface the minutes of the [first] Entomological Society of London with those of the [third] Aurelian Society and so to preserve much valuable information. It continues by stating that the meetings held from 1801 until August 1804 were much less formal than the succeeding ones. Apart from the extract of the minutes quoted on p. 51 relating to the Society of Entomologists of London, the minutes relate almost entirely to the recording of purely entomological information communicated to the meetings by the members and others. The very small balance is concerned with the election of members and similar matters. So much for the copy of the minute book, and now to proceed to the information concerning the Aurelian Society which I have traced.

The first source of information is Haworth (1803) in the dedication of his celebrated *Lepidoptera Britannica* : " To the Gentlemen of the Aurelian Society, who have given up with unexampled zeal, from their respective collections, to the Aurelian Cabinet, every British Insect which that did not possess, the following account of the Lepidoptera of Great Britain is most humbly inscribed, as a testimony of gratitude and esteem, by their greatly obliged and very humble servant A. H. Haworth, Founder and Curator of the Aurelian Cabinet." It may here be remarked that, as will be shown later, the so-called " Aurelian Cabinet " was in fact nothing more than Haworth's private collection and such gifts as were made to it by the members were, at any rate in part, returned to the donors when the Society was re-formed as the [first] Entomological Society of London. To refer again to Haworth's *Lepidoptera Britannica*, in the Preface (page xiii) he said : " Prior to the publication of my *Prodromus* [issued anony-

mously in 1801], I had endeavoured, and nearly succeeded in my endeavour, to establish an *Aurelian Society*; *and a standard, permanent, and complete collection of British Lepidoptera* ; under the name of the *Aurelian Cabinet.*

" This collection, containing (with the exception of about seventy species, and a few Tineae,) all the *known British Lepidoptera*, and a very considerable portion of insects in the other orders; it is my intention to give to the *Aurelian Society, bonâ fide, and without fee or reward*; as soon as it shall amount to twenty living members; to be kept up by them and their successors, for ever hereafter, as a *standard and permanent collection of British insects* : in such manner as I shall elsewhere direct, for the benefit and advantage of this my favourite department of the science of Entomology.

" The Society at present consists of about 10 members only. They are all *collectors of British insects, and possess collections* : and it is by no means unworthy of remark, that they have every one hitherto contributed articles to the *Cabinet*, which could not have been procured from any other source whatever. All these gentlemen have given up, with unexampled zeal, from their respective collections, to the *Aurelian Cabinet*, every [page xiv] *British insect* which that did not contain; thus assembling together the most extensive collection in British Entomology hitherto made.

" The leading objects of the *Aurelian Society* are, *to form a complete and standard cabinet of the Entomological productions of Great Britain :—to ascertain their names and distinctions—*' Nomina si nescis, perit et cognitio rerum '—*their times and places of appearance : food : œconomy and peculiarities : and to point out to the public the readiest and most desirable methods of destroying such as possess properties which are inimical to the welfare of mankind.*

" Having now spoken sufficiently of the institution and views of the above society, I shall beg leave to explain the nature and novelty of the genera and sections into which the genus *Phalaena* of Linnaeus is divided in the present work."

This gives a clear picture of the aims of the [third] Aurelian Society, so clearly the product of Haworth's direction, and of his attempt to build up a representative British collection of Lepidoptera. It is interesting to note the suggestion of applying entomological knowledge to assist the " welfare of mankind " ; nowadays it is unusual for Entomological Societies to be so ambitious. As will be shown later, Haworth's promise was not redeemed since the Society never reached the total membership which he made a condition for the offer of his collection.

Later in the same Preface referred to above (page xviii) Haworth said : " On my mentioning to Mr. Curtis, [William Curtis 1746–1799] some time before his death, my intention of attempting the establishment of a society to collect and explain *all the natural productions of Great Britain*, or at the very least the *entomological ones*, he assured me he had once meditated a similar thing himself, under the appellation of *Musaeolum Britannicum*; and as he had abandoned the idea of pursuing it, he presented me *his collection of British insects*, to encourage me to do so."

Further proof of Haworth's control of the affairs of the Society is to be obtained from the following, which is to be found on page xxxi of the *Lepidoptera Britannica* :

" Terms of becoming a member of the Aurelian Society.

" Any person desirous of becoming a Member of this Society, must be approved by every one of the Members for the time being; and if he possesses a collection of British Insects, he must give up from it, to the *Aurelian Cabinet*,

at least one specimen of every species and variety, which the latter does not
possess : for which he will immediately receive from the Curator [*i.e.* Haworth]
of the Cabinet for the time being, the fullest value in rare insects; or money if
he chose to accept it; and afterwards occasional duplicates of scarce Insects,
which will continue to be collected, both by purchase and personal industry;
to answer the claims of such *Aurelians* as may hereafter wish to have their names
enrolled in the annals of the society.

"The above sacrifice of rare or unique species, considering the truly advanced
state of the (a) *Aurelian Collection* (the most extensive in British Entomology
hitherto made) can seldom be great, and will evidently become less and less.

"By these means the Aurelian Cabinet must ultimately arrive at the
standard of perfection; and the separate collection of every Member of the
Society will gradually increase both in number and value.

"The Members will have a right of inspecting the Cabinet as often as
they please, either for the purpose of pleasure or instruction."

"(a) This Cabinet, and all the British Insects it contains, I here pledge myself to give
up to the *Aurelian Society*, bonâ fide, and without fee or reward, as soon as the Society
shall amount to 20 living Members, in such manner as I shall then explain. *Vide page* xiii.
of the Preface."

All the above quoted passages were published in Part 1 of Haworth's
work which was published in 1803 (Griffin, 1932). The book was completed
by the appearance of Part 4 in 1828 (Griffin, 1932) and in this last part Haworth
obligingly completed the story of the Society. On page 587 he said : "Post-
script. A few observations on some of the earlier pages of the preceding
work appear to be requisite : viz. page 13 [*recte* xiii] of the Preface, &c.

"The young Society there mentioned never amounted to twenty living
members, and was dissolved in April 1806, on account of the giving up of
rare insects, as there stated, to form a general Cabinet, being very much dis-
liked, and motioned against at its meetings. But on its dissolution, a new
society was immediately formed of very nearly the same members (requiring
no insect to be given up), all the members of the old society withdrawing
all, or any of their respective contributions towards one general cabinet, as
they pleased."

The minute book already referred to, which it will be remembered was
written by Haworth, does not give any information on this matter of the
giving up to the Cabinet such insects as the Cabinet did not contain. Haworth's
omission is understandable in the circumstances, for he obviously set great
store on his ideal of a complete collection. The "Postscript" continues :—

"The new Society was at first called 'The Entomological Society'; and
afterwards, 'The Entomological Society of London.' The old cabinet was
called 'The Entomological Cabinet' : and a small cabinet of British insects,
which was soon after given to the new Society by the writer, was called 'The
Cabinet of the Entomological Society of London'; but has since received no
good arrangement, and scarcely any additions. [For the story of this Cabinet,
see p. 67.] The new Society became known by its name of 'The Entomo-
logical Society of London'; and published the third and last Part of its
Transactions (whose well-meant motto [3] was given by the writer) in the year
1812. But, after that period, through the death of some of the members,
and the resignation, neglect, or departure from London of others, only held
quarterly, yearly, or occasional meetings, until the year 1822; when the

[3] Insectorum historiam elaborare.

Society (although reduced to about half a dozen members) rallied, and elected several new ones; who soon after, (joined by most of the old ones,) formed another Society, by the name of ' The Entomological Society of Great Britain,' without dissolving ' The Entomological Society of London,' only adjourning it for one year; but detaching themselves therefrom, by withdrawing their subscriptions. And the Treasurer, who repaid the same, yet holds the very trifling remaining funds of ' The Entomological Society of London,' together with the above-mentioned small cabinet of British Insects, and a few papers belonging thereto.

" ' The Entomological Society of Great Britain ' was also adjourned for one year. And after this, most of the members of both the last-mentioned Societies were joined by various Fellows of ' The Linnean Society of London,' under the shape and name of a Club; and became ' The Zoological Club ' of that Society."

In the "History " by Surr (1812) already mentioned, he, having quoted the objects for which the [second] Aurelian Society, " the progenitor of the present [The [first] Entomological Society of London], and which was instituted in the summer of 1801," was established, continued : " The ultimate end of all science, its application to the comfort and convenience of man, was not, as appears above, overlooked by the Aurelian Society. Great industry in collecting was exerted, and great liberality was displayed, by its members, towards forming a Cabinet. As their numbers increased, and their views enlarged, they altered their title to that of the Entomological Society in 1805, and finally in 1806 to that of the Entomological Society of London, embracing the study of Foreign Entomology, but more especially restricting themselves to the Insects of the United Kingdoms : it may safely be said that for industry, its members have been exceeded by few."

For the rest this " History " is little more than an appeal for general support for the *Transactions*, communications being " invited from Entomologists in general"; the Cabinet and the Library; and concluding with the expression of the hope " that the practical Entomologist may find it worth his while to enroll himself amongst its members and supporters."

It is perhaps as well to give here the story of the " History " by Surr mentioned above (p. 51), as I can trace it. In the minute book of the [first] Entomological Society of London, now in the care of the Royal Entomological Society of London, the minutes of a committee meeting held on 10 March 1806 record the recommendation that " this history of the Society be printed as a separate paper for distribution if the same be approved." The paper was read by the President, Haworth, for the Secretary, Surr, at the meeting on 3 December, 1806. For some reason which is not recorded it was apparently unsuitable, or at least unacceptable, to the Society and it was not accepted for publication. It was next read in altered form at the meeting in January 1807. It is probable that it is the paper printed in very abbreviated form as the " Introduction " to Volume 1 of the *Transactions of the* [first] *Entomological Society of London* and which was published with Part 3 of the volume in 1812.

As may be seen, I have deliberately included in some of the above quotations passages which concern more closely the [first] Entomological Society of London, which succeeded the [third] Aurelian Society, than this latter Society. I do this because the relationship between the two Societies is obviously so close that it would be difficult to produce otherwise a connected narrative. It cannot be stressed too often how closely interwoven are these

early Societies, and the activities of their members, and since my object is to endeavour to produce as clear a picture as possible it seems best to adopt the procedure above.

I have extracted from the minute book of the [third] Aurelian Society a list of the members, and whilst I am unable to guarantee that this list is full and complete, it does contain the name of every person mentioned as being a member. The list is printed in the order of the reference to the names in the minute book :—

A. H. Haworth, Little Chelsea   J. Howard, Kingsland
Revd. J. Burrell,   T. G. Ingall,
W. Skrimshire, Wisbeach   Revd. Dr. Abbott [also as Abbot],
Revd. T. Skrimshire, Fakenham   P. W. Watson,
Dr. F. Skrimshire,   R. Scales, Walworth
J. Rippon, York   Wm. Anderson, Kensington
J. Hatchett,

The next source of my information is the Syer Cuming collection of papers, described later. In this collection is to be found a document as follows :—

" Decr. 1802. Proposals for the *Meetings* of the *Aurelian Society*.   1st. *Mr. Haworth* proposes, that as many of the Members of this Society as can make it convenient, shall meet at the hour of 4 o'Clock in the evening, on the first day of every Month, at . . . . . ., for the purposes of *exhibiting & giving applicable English Names*, to such British Insects of the *Order Lepidoptera*, as have at present, either *no settled English appellation* : or such as are uncharacteristic or objectionable.

" 2d. *That* the Member who first exhibits any species shall have the right of proposing any name he pleases for it; before any other person shall have a right to propose one.

" 3d. *That* if the person presenting such species shall refuse to offer any name; the President (who shall be chosen by ye Members at their first meeting) shall ask if any other Member or Members have any other name or names to propose for ye same article.

" 4th. *That* if no name at all is proposed, the President himself shall be obligated to propose one, unless, it shd. be thought advisable to defer the naming of the article to some future meeting.

" 5th. *That* then the President shall repeat the name or names proposed; with the name or names of their proposer or proposers; before the members assembled, & shall request them to decide by open vote, which is the best; this shall be determined by a majority of their votes; the vote of the President being a casting one, or equal to two votes.

" 6th. *That* the name which is decreed to be the best and most appropriate, shall be confirmed & established; by entering it in a Book, which shall be called the *Society's Journal*; and also in the *Catalogue of the Aurelian Collection* & be referred from thence to its proper number in the *Aurelian Cabinet*, (if it is there) which number shall ever afterwards, be considered & held, by all the Members of the *Aurelian Society*; as a *standard & permanent reference for the name it belongs to.*

" 7th. *That* if any article presented & named as above shall be new to the Aurelian Cabinet; it shall be presented by ye owner of it to that Cabinet;

who shall immediately receive ye thanks of the Society, (by the Declaration of the President,) for so valuable addition to their common stock.

" 8th. *That* the circumstance of the Donation with the name of the Donor; shall be entered in in the Society's Journal Book, accompanied by the time & place of the capture of ye Insect, with its age & *state of Life*, at the time of its caption.

" 9th. *That* every Member who shall furnish an account of the time or place of any rare species being in the *Larva*, *Puppa* or *Imago state*, with any peculiarities appertaining to them; or any of them; shall have the public thanks of ye Society for so doing : and shall have their kind information inserted in the Journal of the Society (which shall be kept by ye President,) except such information is already inserted there from some other source.

" 9th. [sic] *Mr. Haworth* will engage to entertain the Members at any time assembled, (when there shall happen to be no naming, or other business in hand) with Entomological Anecdotes, or with Lectures, which shall be explanatory of *some or other*; and in time of *all* the technical parts used in the Science of Entomology; so as to divest them of their intricacy, & render them perfectly easy, familiar & intelligible, to all the Members. This he will do by exemplifying each part with a suitable reference to ye real corresponding part in real specimens; which he will make it at once his pleasure & his business, to procure for those very purposes."

This document is most interesting and I cannot find that it has been published previously. It is improbable that any such proposals for naming animals would be accepted to-day by any science and given validity outside the immediate circle of the small body of members concerned, but one must not forget that the events now being related concern the period at the turn of the eighteenth century. At that time this country was still an island in the old sense of the word and not by any means strongly influenced by what was happening in Natural Sciences even so near as the continent of Europe. Moreover the proposal was for the giving of " applicable English Names " to such as have " no settled English appelation " or with names which are " uncharacteristic or objectionable." With this comment I give below a quotation from a second manuscript document in the same collection of papers. The manuscript is of six leaves and is undated. In my opinion it is written by Haworth and unless " the foregoing sketch of the History and designs of the Entomological Society of London " be the " Introduction " by Surr already mentioned above (p. 57), I am quite unable to trace its present whereabouts. It is possible that the document is incomplete, for it ends at the foot of page [6] in what seems to me an inconclusive manner; it runs as follows :—

" From the foregoing sketch of the History and designs of the Entomological Society of London, the correctness of the following extract from Dr. Rees' Cyclopaedia may readily be appreciated. It is sufficiently well known to the Members of that Society, from circumstances irrelevant to this place, as well as from the Entomological part of Dr. Rees' work, being avowedly conducted by Mr. Donovan, that the remarks contained in it, are the production of that gentleman or some of his friends. It is to be found under the Article Entomology. [page 2] ' The Aurelians pocket Companion by Moses Harris, is a kind of Alphabetical Catalogue of the larger Butterflies, Sphinges & Moths, collected in England by its author : a tract of no utility to the naturalist, unless he first condescends to become an adept in the Jargon of the Aurelian,

or as now termed the Entomological Society; the Insects being throughout designated by the silly names imposed by the few illiterate parsons associated under this denomination. In this English Lexicon of Entomology we have " The Wale ", " The Bank ", " The Turnpike gatekeeper ", " Ghost ", " Old Woman ", " Dishclout ", and a vast [page 3] number of others equally capricious and replete with absurdity.'

" The Aurelians Pocket Companion alluded to in the above extract was published in the year 1775. The Aurelian Society to which it is presumed Mr. Donovan alludes, and which merged with the Entomological Society of London; was instituted during the first years of the present century. Its latter title was taken up in the year 1805.

" The names are most probably to be ascribed to the ordinary collectors long prior to the days of Moses Harris; the Insects are still known by them by the [page 4] titles which Mr. D. derides and they may be obtained of the common collectors ordered by no other names.

" We will now proceed to examine whether they are such fair objects of ridicule as Mr. D. affects to consider them, premising that they most probably, were imposed two or three score years before the present Society had its existence.

" If we consider Butterfly or Moth as generic names ' The Wale ' (Papilio megaera Linn.) was most probably so named from its disposition [to] bask on the sunny [page 5] side of a wall, or from flying to and fro before it in the sunshine. ' The Bank ' is the same Insect but in default of a wall perching on a sunny bank.

" The Gate Keeper, (Papilio pamphilus Linn.) called here Turnpike Gate-keeper, and in Lepidoptera Britannica Small Heath; would seem to be so designated from its being commonly found playing through and through [the bars of a gate, or through] [Note.—The words in square brackets are struck through in pencil.—F. J. G.] a gateway, appearing to enjoy as it were that particular spot, whether the gate be open or no. It seldom moves more than twenty [page 6] yards on either side, and that for a day together unless frightened away. At any rate it would appear to prefer an open course for its flight and as the highway, will afford the least obstruction to it, in woods, it may be found in such situation, from that circumstance.

" The Large Heath of Lepidoptera Britannica, (Papilio pilosellae Linn.) has the same habits.

" The Dishclout (Papilio artemis Linn.) Greasy Fritillary of Lepidoptera Britannica; from its greasy appearance may have had the name of Dishclout amongst the ordinary collectors, but if so it is now discontinued."

The work from which the above extract is made was published in [1809] in volume 13 of the *New Cyclopaedia*. It is a long and interesting chrono-logical account of the published works on Entomology issued in this country, and from the context it is apparent that Donovan was the author, as one may see if reference be made to the passages dealing with Donovan's works. Unfortunately the work carries no pagination, but as I have stated the arrange-ment is chronological and reference is therefore not too difficult.

Since the time of Haworth, who in his *Lep. Brit.* 1803–28 published English names for the whole of the Lepidoptera known to him including the Micros, this matter has interested many people, and a few years ago Sir Edward Poulton, F.R.S., Honorary Life President of our Society, was responsible for the publication of a list of those names used in the eighteenth century especially

by William Jones (Poulton & others, 1934) while Heslop (1938) published a list of British Lepidoptera with English names to the Macrolepidoptera.

This concludes the record of the [third] Aurelian Society, the last to bear the old name, and with its metamorphosis into the [first] Entomological Society of London, the Entomological Society as it is at present understood began to take shape. The selection of the name Entomological in preference to Aurelian is evidence of the interest widening from a restricted interest in British Butterflies to matters relating to insects of all orders and countries from wherever they may come. This tendency is amply evidenced by the contents of the *Transactions* of the successor to the [third] Aurelian Society.

V. The [first] Entomological Society of London [1805–? 1832].

The fifth attempt at the formation of a Society resulted in THE ENTOMO-LOGICAL SOCIETY, later THE [FIRST] ENTOMOLOGICAL SOCIETY OF LONDON formally established in May 1806.

As I have already recorded, this Society was in fact the immediate successor to the [third] Aurelian Society and might even be considered as the same Society with new Bye-Laws and a change of title. The addition of the words " of London " was made in 1806 according to Surr (1812), the original Entomological Society having been established in 1805.

Contemporary documents relating to this Society are more plentiful even than those relating to the earlier Societies and a comparatively full picture of its life and activities is possible.

The two main sources of information available are both original, and comprise the minute book of the Society referred to already (p. 54), and a collection of papers sometime in the possession of H. Syer Cuming and acquired by the Southwark Public Library, by whom they were transferred to the keeping of the Royal Entomological Society of London some years ago. This collection is in a portfolio which opens with a note signed " J. Hatchett " and reading " Papers belonging to the Entomological Society of London." It contains two documents relating to the [third] Aurelian Society already referred to (p. 58); drafts of proceedings of the meetings of the [first] Entomological Society of London from 1806 to 1807; the Treasurer's Lists of Members and notes of their payments for several years between 1806 and 1812; rough notes of the monetary balance in 1807–8, 1808–9, and 1809–10; notes relating to the sale of the Society's *Transactions*; bills for the production of the *Transactions*; receipts for the hire of the meeting room from 1810 to 1812; and three manuscripts as follows : " Continuation of a Catalogue of Hemiptera found in Norfolk. By Revd. J. Burrell No. 10.", this is addressed to Haworth and bears a postmark dated 30 April, 1808; a manuscript entitled : " Recd. Mr. Burrell's Continuation of his Catalogue of Norfolk Insects. Lepidoptera. No. 11. Read November 1, 1808."; and a manuscript entitled; " Description of a few insects presented to Entomological Cabinet by Revd. J. Burrell in July 1809. Read July 4, 1809.", and marked " non imprimatur ".

The first meeting recorded in the minute book is dated 6 May 1806 and was held at the Black Horse, Coventry Street, Haymarket. Earlier meetings, probably of an informal character, had obviously taken place, for the minutes open by saying : " 1. The Society's Bye Laws were read, scrutinized, and approved.—They were ordered to be engrossed and to be ready for signatures, at the Meeting ensuing."

The minutes go on to state that " During the signing [of the Society's Bye-

Laws engrossed on parchment], a discussion took place on the propriety of leaving blank places for admitting the signatures of such of the Members of the late Society [the [third] Aurelian Society], as should hereafter be elected, in the order in which they originally stood. Resolved, that such compliment of preference be paid, to the original institutors, of this Society, and that blanks be left accordingly."

It has already been remarked that the main reason for the dissolution of the [third] Aurelian Society and the establishment of the [first] Entomological Society was dissatisfaction with the rule which required members to give up to the Cabinet of the Society [in fact Haworth's collection] a specimen of any species which that Cabinet did not contain and which was to be found in their collections. It is therefore not surprising that the minutes of the first meetings of the new Society record that various members had exercised their right to re-claim the specimens they had handed over to the general collection.

I have searched the minute book of the [first] Entomological Society of London, and the other original sources, and as a result I am able to give a List of Members of the Society from its inception until it became quiescent and finally ceased to exist. To most names I have added the date of election and it must be understood that those names with no such date are presumed to be original members.

The minutes end with those of the meeting held on 9 July 1822, which conclude : " The meeting adjourned to the first Tuesday in May 1823."

Absolam, Philip, 3.ii.1807
Adams, Joseph, 3.ii.1807
Atkinson, John, 6.xii.1808
Ashby, Edward, 1.xi.1810

Bennett, Edward Turner, 2.iv.1822
Blunt, Edward, 2.iv.1822
Booth, Thomas Swift, 28.v.1822
Burrell, John

Cuming, Richard
Cusack, Christopher, 2.iv.1822

Dale, James Charles, 25.vi.1822
Dawson, Samuel Taylor, 1.xii.1807
Dixon, Frederick, 11.vi.1822

Easingwood, Matthew, 3.ii.1807

Fenton, Ibbettson, –.ix.1806

Gray, John Edward, 2.ix.1822

Hatchett, John
Hatchett, John, junr., 9.x.1818
Haworth, Adrian Hardy
Henslow, John Stevens, 9.vii.1822
Hooker, Joseph
Hope, Frederick William, 2.iv.1822
Howard, John

Ingall, Thomas George

Ingall, Thomas, 2.iv.1822

Leach, William Elford, 6.xii.1808

Neale, Edward Pote, 14.iii.1822
Neale, John Preston, –.vi.1806

Pears, Charles, 6.x.1807
Pittard, John, –.vi.1806

Salisbury, William, 1.ix.1807
Salter, Philip, 5.ii.1811
Samouelle, George, 2.iv.1822
Savage, James, 5.viii.1806
Savage, William, 5.viii.1806
Scales, John, 9.x.1818
Scales, Robert
Simpson, W. R., 4.xi.1806
Skrimshire, Thomas
Skrimshire, William
Stephens, James Francis, 11.vi.1822
Stone, W., 28.v.1822
Sowerby, George Brettingham, 7.iv.1807
Surr, James, –.vi.1806

Vigors, Nicholas Aylward, 2.iv.1822

Watson, P. W.
Webster, Thomas, 5.ix.1809
Wilkin, Samuel, 1.ix.1807

A grand total of 48 members.

The following Officers were elected at the first meeting on 6 May 1806 :—

> President : A. H. Haworth.
> Vice-President : R. Scales.
> Treasurer : T. G. Ingall.

It will be observed that no Secretary was appointed, but this omission was repaired at the next meeting, when J. Surr was elected a member and appointed Secretary.

In 1807 and in 1808 the Officers were elected without change, the first change being in 1809, when Hatchett was elected Vice-President but later declined to accept office. In 1810 the existing Officers were confirmed in their offices and the next election was deferred from the usual month of May until 5 November, when the following elections were made :

> President : A. H. Haworth.
> Vice-President : I. Fenton.
> Treasurer : T. G. Ingall.
> Secretary : E. Ashby.

The next year Surr replaced Fenton as Vice-President but no other change was made. In 1813 the only change was the election of Neale to the Secretary-ship. In 1814 no change was made and no further election was held until 23 May 1817, when it was recorded that " . . . The Officers elected for the year 1815, be considered as having held their offices from that time to the present, and that they still continue, to hold their seats." The death of Ingall the Treasurer was, however, recorded at the same meeting and accordingly a new Treasurer was elected, the choice falling on Hatchett.

In June 1819 it was resolved " That the Officers of the preceding year be continued in their offices for the present," and a similar resolution was adopted on 9 October 1821.

The next election occurred on 7 May 1822 with the following result :—

> President : A. H. Haworth.
> Treasurer : J. Hatchett.
> Secretary : J. E. Gray.

the office of Vice-President being left vacant " untill the Society should become more numerous." This is the last recorded information as to those responsible for the direction of the Society's affairs and the Society appears to have become dormant soon after this meeting.

This Society was the first to attempt the publication of a periodical devoted to Entomology. The first mention of the publication of *Transactions* was at the meeting on 4 November 1806 when a Committee was nominated " . . . to examine the Society's papers and to report their opinion on the same at the next meeting, declaring which of them they deem proper for the Society to print." The Committee consisted of Haworth, Scales, Surr, J. Savage, and W. Savage. They reported to the next meeting as follows :—

" Your Committee are of opinion, that it will be advisable to publish Communications under the Title of ' The Journals of The Entomological Society of London '—that they be printed in octavo in the same sized type and paper as ' Anderson's Recreations '—that they be published in numbers, as often as

the Society may deem it expedient; and with occasional plates when the subject shall be thought of sufficient importance.

" After examining the papers already in the possession of the Society, your Committee recommend that the President's ' History of British Entomology ', be the first in order and followed by that of Mr. Thos. Skrimshire on rearing insects (read Sept. 1805) and the Rev. Jno. Burrell's Description of Lygaeus micropterus read Sept. 1806—and that these form the first Number of the said Journal.

" Your Committee are of the opinion that the History of the Entomological Society promised by Mr. Surr, and referred to by Mr. Haworth in his History of Entomology, will form a proper Introduction to the Journals, and recommend that this History of the Society be printed as a separate paper for distribution if the same be approved.[4]

" Your Committee are likewise of opinion that it would be advisable to adopt the Resolution of the Royal Society, in reference to the Contents of any papers they may publish, the import of which is, that the Society pledges itself to nothing advanced in any Communications published in the Journals.

" Your Committee strongly recommend that no anonymus [sic] paper whatever be permitted to have place in the Society's Journals.

(Signed) A. H. Haworth."

The report was presented but consideration was deferred until " Mr. W. Savage offered to obviate all objections on account of the funds, to take on himself the expense and risk of printing the Journals," and it was " Resolved : that the thanks of this Society, be presented Mr. W. Savage for his offer." I cannot trace any further reference to this offer and it seems likely that it was not accepted.

In February 1807 it was suggested that a committee be set up to consider revising the rules of the Society and in March the following were nominated a Committee to revise the Bye-Laws : Hatchett, Ingall, Howard, Neale, and J. Savage. This action seems to indicate that the original Bye-Laws gave no authority for the publication of a Journal.

The report of this Committee was promptly produced but suffered a long delay from the action of Savage, who offered " to copy [the report], in a manner fit to be presented to the Society ", so that the Committee were compelled to add a note as follows : " Your Committee, under the Idea, that printing the Transactions of the Society may experience further delay, by their unfortunately being disappointed of making their expected Report upon the present Rules— Recommend that the opinion of the late Committee upon the printing the papers therein mentioned, be immediately carried into effect."

This was reported to the meeting on 21 April 1807 and detailed consideration was given to it at the three following meetings, when it was adopted. On 5 May 1807 it was resolved : " That a Committee be appointed to examine such communications & papers as are in possession of the Society for the purpose of publication. On a Ballot the following persons were elected, viz. Mr. Hatchett, Mr. Haworth, Mr. T. G. Ingall, Mr. Neale, Mr. Pittard, Mr. W. Savage, Mr. Scales, Mr. Surr three of whom shall be competent to act."

At their first meeting on 5 May 1807 the Committee adopted several resolutions and accepted certain papers for publication in the *Transactions*. They decided that the *Transactions* should be printed in a small pica type in octavo; that Mr. W. Savage be employed to print the *Transactions*; and that

the first part should be published on 1 June 1807. This early date, which left less than one month for the editing of the part, could obviously not be kept and at the meeting on 2 June it was decided that the *Transactions* should be published by Mr. White, Mr. Murray and Mr. H. D. Symmonds ; that part 1 should appear on 1 July ; that it be priced five shillings ; and that it be accompanied by four copper plates. Mr. Neale presented the drawings and engravings of three of these plates and Haworth the drawing and engraving of the fourth. The next mention, apart from recording the Society's thanks for the drawings, was the receipt of the bill for printing in October. This amounted to £24 8s. 4d

In June 1808 a Committee was again set up to report which papers " are proper to be printed as the second Number of the Society's Transactions." The Committee consisted of Surr, Scales, Hatchett, Fenton and Haworth, but Surr retired from reasons of health and was replaced by Easingwood. In July they recommended papers for inclusion in part 2 " provided that said papers do not all together exceed four sheets of letterpress."

In due course this was accepted and it was agreed to add two plates to the four sheets of letterpress, but in December 1808 a number of donations were announced which permitted an increase to seven sheets. The donations were :—

> Mr. Hatchett 2 engraved plates
> Rev. Mr. Burrell 1 sheet of letterpress
> Mr. W. Savage 1 sheet of letterpress
> Mr. G. B. Sowerby 1 copper plate and one guinea
> Mr. J. P. Neale half-a-guinea
> Mr. Surr half-a-guinea
> Mr. Easingwood half-a-guinea
> Mr. T. G. Ingall half-a-guinea.

To this list the following were added in January 1809 :—

> Rev. Mr. Burrell 1 additional sheet of letterpress
> Mr. Haworth 1 sheet of letterpress
> Mr. Leach 1 engraved plate
> Mr. Fenton one guinea

Consideration was next given to the price of part 2 and in February this was fixed at half-a-guinea but subsequently the decision was ruled to be *ultra vires* because insufficient notice of the motion had been given and on reconsideration it was agreed that the price be seven shillings and sixpence.

From various references in the minute book it seems clear that the members of the Society were very jealous of their rights under the Bye-Laws, and on several occasions attention was drawn to decisions said not to be in harmony with them. One such was in connection with the publication of part 2 of the *Transactions* and on 2 May 1809 a " Report of the Printing Committee " was made as follows :—

" Your Committee reports, that it took into consideration, the second part of the Transactions of the Society, according to the reference made to it, and referred to the Report of the Printing Committee of July 5th 1808 and the Minutes of the Society since that period and finds that Mr. Hatchett's paper on ' Some rare British Moths ', Mr. Sowerby's ' Account of a new Scarabaeus and observations on two other rare insects ', Mr. Leach's ' Account of two species of

Clytra' and the 'Extracts from the Minutes' have not been ordered to be printed conformably to the Bye Laws, although they have been read before the Society. And the Committee recommend to the Society in future, not to order any Article to be printed in its Transactions, but what have been regularly referred to a Committee, according to the Bye Laws of the Society; and all communications ordered for publication should be printed according to the dates on which they have been read before the Society.

<div align="right">

(Signed) Wm. Savage (Chairman)
J. Hatchett
J. P. Neale
J. Fenton
G. B. Sowerby
S. T. Dawson."

</div>

In order to regularise what apparently was an irregular position under the Bye-Laws it was " Ordered that the second part of the Society's Transactions, be forthwith published."

The next reference to the *Transactions* was in April 1811, when a Committee was again set up. This time it was to " consider the expediency of proceeding to print another, being the third part of, and completing Volume the first, of the Society's Transactions." The Meeting turned itself into the Committee and immediately produced a Report that it was better to defer the matter. On 7 November 1811 they reported as follows :—

" Your Committee recommend that the third part, concluding the first Volume of the Society's Transactions be printed immediately; and that the following Papers do constitute the same." The list is then given. It was further decided to accept a plate offered by Neale and one by Hatchett and that Mr. Taylor should print the part.

At the September 1812 meeting it was resolved that " the whole of Part III of the printed Transactions reserving fifty copies, be placed in the hands of Mr. Underwood . . ." further that the price of the part be five shillings and six-pence and that it be published forthwith. At the same time it was decided to give the Binder directions to cancel the title-page and table of contents to part I already issued.

In 1813 Mr. Thomas Underwood of 32 Fleet Street and 40 Smithfield was appointed " sole publisher " of the *Transactions*. From the minutes of the meeting in February 1813 it seems that the number of the edition was 250 copies, since it is recorded that the Vice-President had received 50 copies in quires and Mr. Underwood had received 200 copies. The bill for printing this third part was considered in November 1813; it amounted to £22 13s. 0d. for the 250 copies, and it was ordered that £15 be paid on account. The balance was ordered to be paid at the meeting in June 1817. Obviously the Society was not wealthy ! On 11 June 1822 it was reported that the Treasurer held 103 copies of part 1, 135 of part 2, and 50 of part 3. No further information concerning the *Transactions* is to be found in the minute book.

I cannot trace that the [first] Entomological Society of London attempted the formation of a Library but they obviously formed a " Cabinet " of insects, for the most frequent entry in the minutes is a " report on the state of the Cabinet with a list of additions." From the minute of 1 May 1810, and of February 1811, however, it is apparent that the Cabinet referred to up to that date was in fact the private collection of Haworth, the President. It reads :

" The President having offered a collection of British Insects as a gift to the Society, containing about 2000 species, Resolved unanimously : That this liberal offer be accepted, and that the thanks of this Society be presented the President for his valuable gift." In November 1810 the receipt of the collection was recorded and the President thanked. In February 1811 the following resolutions were adopted : " That the thanks of the Society be presented the President for the valuable information, from time to time, communicated to this Society, respecting the progress of his private collection of Insects hereto-fore known by the name of the Entomological Cabinet. The Society being now in possession of a Cabinet resolved that the said Cabinet be called ' The Cabinet of the Entomological Society of London. Resolved that future reports respecting the progress of the Cabinet be understood to refer exclusively to the said Society's Cabinet.' From that time relatively few additions were recorded and the subsequent history of the Collection is not known to me. As stated on p. 56, it is clear that no satisfactory arrangements were made for the care of the collection and it is probable that the neglect complained of by Haworth (1828) was real in fact.

The first meetings of the Society were held at the " Black Horse," Coventry Street, until April 1807, when one meeting was held at the " Crown," Stationer's Court, Ludgate Street. The next move was to 35, West Smithfield, followed by a meeting at the house of Savage at 28, Bedfordbury. In June 1807 the Society moved its place of meeting to the Russell Coffee House, Covent Garden, where it continued to meet till September 1812. From November 1812 it met at Surr's house, 53, Aldersgate Street, until June 1818. At this time there is a break in the minutes which continues until the meeting in October 1818 held in Neale's house in Bennett Street, Blackfriars, where they continued to be held till April 1822. The next two meetings were held at the house of J. E. Gray at 10, Hatton Garden, and the last three recorded meetings took place in June and July 1822 in the Anatomical Theatre at 87, Hatton Garden, belonging to Mr. J. E. Taunton, Surgeon, and Mr. Cusack, Professor of Anatomy and Surgery.

For the use of the room at the Russell Coffee House a fee of half-a-guinea per month was charged and many of the receipts for payment are still preserved in the Syer Cuming collection of papers.

The subscription to the Society was, as far as my information goes, originally ten shillings, being raised in March 1808 to one guinea. In addition to the subscription it seems that a fee of one shilling per meeting was charged whether a member was present or not. As might well be expected this arrangement did not work satisfactorily and the principle was eventually given up and all out-standing arrears written off. The sum was relatively not inconsiderable.

This then is the story of the first Entomological Society of London as far as I am able to trace it. It may be seen that a last attempt to revive it was made in 1822, when several new members were elected. Attention is drawn to these men, for several of them were later to play an active part in the establish-ment of the present Royal Entomological Society of London. For one reason or another the effort was fruitless. The time for specialisation was not yet; no doubt the times were restless, for the Napoleonic wars were raging in Europe and this country then, as now, was deeply involved. The dominating per-sonality of Haworth was perhaps declining, or had the challenge to his leadership begun ?

I may conclude with the quotation of a small, somewhat dirty, scrap of paper on which is written, I believe in the writing of Gray, " Entomological Society Cabinet.   To Balance in Hand £2 = 17 = 3.   Decr. 1832.   I hold this Balance in hand when it is settled who takes the Cabinet I think must receive it but take a receipt.   Mr. Haworth must get settled think he will be the right Person to take it."   I am unable to discover who took the balance but the slip is now in the Syer Cuming papers in the keeping of the Royal Entomological Society of London.

VI. The Norwich Entomological Society [c. 1810].

In the meantime the Norwich Entomological Society was established.   Of this Society I have traced no further information than is given by Westwood (1864).   Apparently the Society flourished in 1810, the 3rd meeting being held on 4 December 1810, when papers were read by Mr. Curtis and Mr. Wilkin. From the MSS. page of the Proceedings exhibited by Prof. Westwood to the present Royal Entomological Society of London it is evident that Rev. W. Kirby was elected a member.   How long the Society persisted is not recorded.

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ON THE MECHANISM OF COPULATION IN *NEMATUS RIBESII* (SCOP.) (HYM.)

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Communicated by Dr. A. D. IMMS, F.R.S., F.R.E.S.

INTRODUCTION.

THE present study was undertaken in the hope of finding out the functions of the structures concerned in copulation, for the value of a character can be properly rated only if its function in the life-cycle of the species is understood. Useful accounts on copulation in various insects have been given by Berlese (1909), Weber (1933), and recently Wigglesworth (1939) has briefly reviewed the problem. Little previous work, however, has been done on the order Hymenoptera. Many investigators have studied mating in the honey bee, and as this insect mates in the air conclusions are drawn from indirect evidence. Besides, the penis of the bee is a highly modified organ with its different parts having different functions. Most authors have, therefore, laid importance on the rôle of the penis and neglected the functions of the claspers. Rohwer in 1915 published a brief account of the mating habits of some sawflies. He stated that the outer claspers have a gripping function, but he failed to record the functions of the penis and the inner claspers. Whereas clasping had been shown by Wheeler (1913), Rohwer (1915) and Donisthorpe (1927) to be the function of the outer claspers, it had been only indirectly inferred as the function of the inner claspers (Wheeler, Donisthorpe). Very recently Peck (1937) working with *Angitia fenestralis* and Clausen (1938) with the ant, attribute a clasping function to both the pairs of claspers. Finally the mechanism of the migration of the sperms from the bursa or the vagina to the spermatheca is uncertain. The present study attempts to clarify some of these uncertainties.

MATERIAL AND METHODS.

The specimens under investigation were reared in large jars in the laboratory during the summer months. Chloroform and ether were used for killing the insects while in the act of copulation. Musculature was studied mainly from dissections of fresh specimens. Sections were stained in Heidenhain's iron-haematoxylin and counterstained in orange G; and also in Delafield's haematoxylin and counterstained in eosin.

THE PROCESS OF COPULATION.

The genitalia of the adult become inverted shortly after emergence turning through an angle of 180°, and the inversion may be from the right to the left or vice versa. The copulatory organ alone is inverted and, therefore, its component parts do not suffer torsion. The process involves a twist in the muscles connecting it to the hypandrium (ninth sternum). The apophyses of the hypandrium acts as a pivot in the process. The internal reproductive organs, especially the accessory glands, seminal vesicles and the vasa deferentia, become twisted, while the testes are retained in position by the gut above which they are attached to each other along their median margin. Inversion of the genitalia always precedes pairing. The male exhibits interest in the

female by the vibration of the antennae and the wings. Mating takes place end to end with the two individuals facing opposite directions. When the male is a few centimetres from the female his wing movements become very rapid and he shunts backwards with his copulatory apparatus spread open. During this time the female remains ready to receive him. Over a dozen specimens were killed in copulation and they all showed very clearly the following condition (fig. 1). The subgenital plate (seventh sternum) of the female is gripped by the outer claspers from the outside, while the inner claspers press against it from the inside, thus serving an antagonistic function to the outer. The penis is inserted deep into the vagina and its valves open wide apart while its tip lies well under the spermathecal opening into the vagina. This is clearly shown in dissections of specimens in copulation and also from serial sections of the insects fixed in copulation (fig. 2, A, B). The sperms (s) are ejaculated in a mass into the vagina (v) along with the secretion (agf) from the male accessory gland (fig. 2, B). That this secretion came from the male accessory gland was confirmed by sectioning females which had not mated. In them it
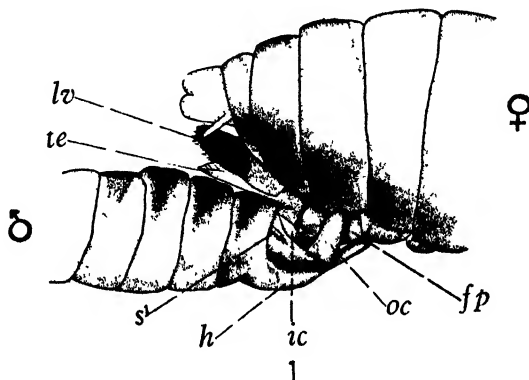
Fig. 1.—The insects in copulation. Lateral view.

fp = subgenital plate (7th sternum of female); h = hypandrium (9th sternum of male); ic = inner clasper; lv = lateral valve; oc = outer clasper; s' = socci; te = terebra.

was absent. A female fixed half an hour after mating showed that the sperms (s) travel up to the spermatheca (sp), and that only the free sperms reach it, while those that are held in bundles are still in the vagina (fig. 2, C). A fertilised female sectioned six hours after copulation showed that all sperms had entered the spermatheca, none being left in the vagina, and the secretion from the male accessory gland was absorbed. The spermatheca, in the newly emerged female, is a circular structure lined internally with a thick cuticular layer. Its inner ventral wall shows a collection of cells like that of a gland (fig. 4, A). The spermatheca of the female, which was sectioned six hours after fertilisation, shows this glandular region spread out into short villi-like structures pointing internally, like the opening of a flower-bud (fig. 4, B). The duct, as well as the inner wall of the spermatheca, appears muscular. The individuals remain motionless during pairing, which lasts on an average 45 seconds. After the act the individuals "dress" their genitalia with their hind legs. The male becomes sluggish and does not accept another female immediately but, an hour or so later, the same male was seen to mate with another unfertilised female. I have observed a male mating with six different females. When a male came

across a fertilised female he vibrated his antennae and soon found out that the female was fertilised and showed no further interest in her. This was confirmed by keeping males separate in order to starve them sexually. When such males were offered fertilised females, they refused to mate, but when offered unfertilised ones they mated readily. It therefore appears that the females mate only once in their lifetime.
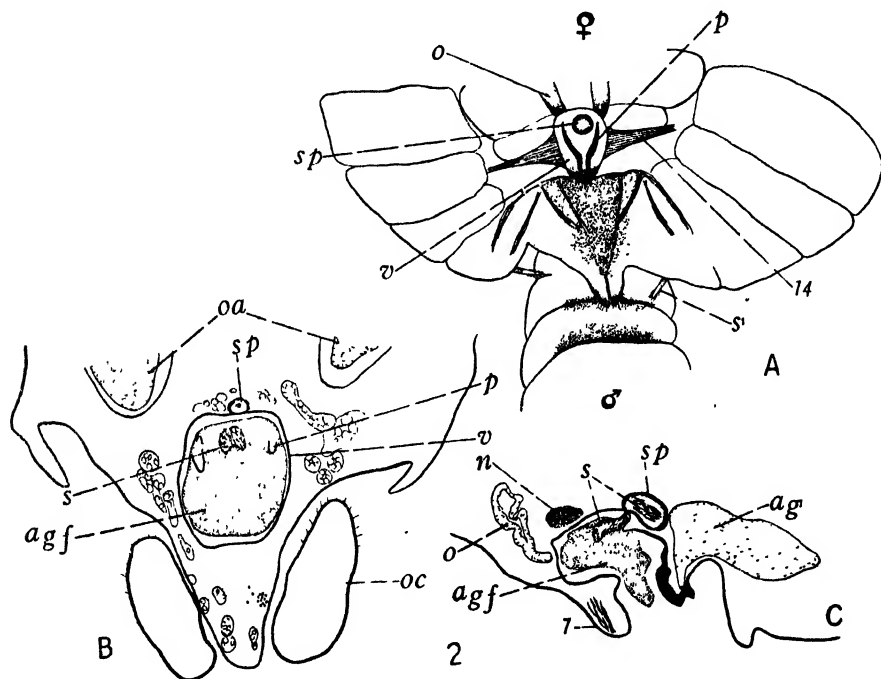
Fig. 2.—A. Dissection of the insects in copulation to show the position of the penis inside the vagina (dorsal view).
   B. T.S. of a pair in copulation.
   C. L.S. of a female half-hour after mating to show the migration of the sperms into the spermatheca.

agf = secretion from the male accessory gland; *ag′* = female accessory gland; *n* = nerve ganglion; *o* = oviduct; *oa* = ova; *oc* = outer clasper; *p* = penis; *s* = sperm; *s′* = socci; *sp* = spermatheca; *v* = vagina; 7 = seventh sternum of female; 14 = muscle.

Egg Laying.

For this purpose, freshly emerged females were placed along with the leaves of the host-plant in a tube. The process was observed under a binocular microscope. Once the female starts the process, she becomes so absorbed in her work that the tube can be tilted in any direction without disturbing her. She first seeks a suitable spot along one of the veins, generally on the underside of the leaf, then flexes her abdomen which brings the terebrae at right angles to the leaf surface. The saws then begin to move alternately, making a path for the terebrae into the leaf tissue. When they have excavated a small pocket, their movements cease. A short interval follows and then one observes heaving

movements in the abdomen above the ovipositor. Soon an egg is seen to come in between the saws, and the movements of the saws are resumed. The egg descends into the pocket with its narrower end facing it. At this time the rôle of the saws is over. Their sheath, which serves not only to lower the egg to the leaf surface, but also cuts along its course a narrow incision, is then gradually
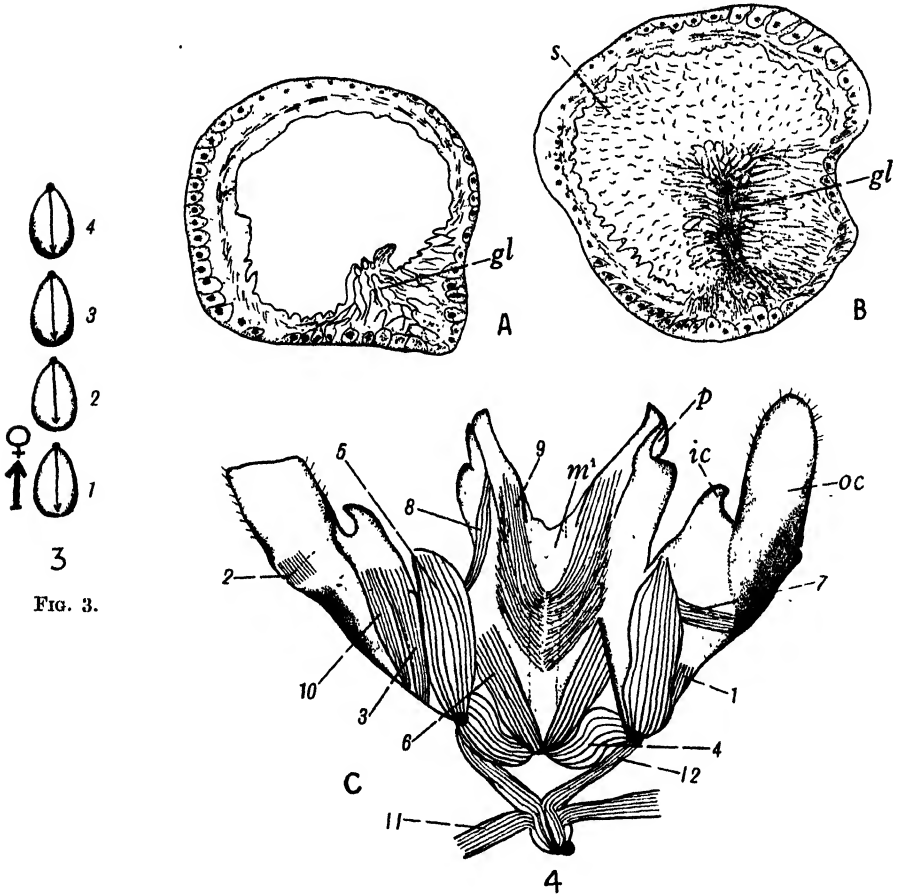
FIG. 3.

FIG. 4.—A. T.S. of the spermatheca to show the glandular structure of a newly emerged female.
      B. T.S. of the spermatheca to show the active glandular structure of a female six hours after fertilisation.
      C. The musculature of the male genitalia.

1-12 = muscles of male genitalia; gl = glandular structure in the spermatheca; ic = inner clasper; m' = membrane attaching the two penes; oc = outer clasper; p = penis.

drawn back. The fly then withdraws its ovipositor and walks one step forward and lays another egg exactly in the same manner. Fig. 3 shows diagrammatically the entire process. Four eggs are shown marked 1–4. The direction of the insect is indicated by an arrow on the left of the figure. The cavity which is excavated by the saw is represented by a big dot on the narrower part of each

egg, and the vertical arrow directed backwards in the centre of each egg represents the incision made by the sheath as it is drawn back. If the leaf is left to wither the egg dies.

MUSCULATURE—OVIPOSITOR.

Observations by Keir (1936) on the musculature of the ovipositor of the sawfly *Thrinax* are in complete agreement with my observations on *Nematus* (for illustration and description of the muscles *vide* Keir).

Male (fig. 4, C).

Snodgrass (1935) gave diagrams of the male genitalia of *Pteronidea* (*Nematus*) *ribesii* figuring most of the associated muscles, but with no accompanying description.

No. 1. *Retractor of Outer Clasper.*

From the dorsal basal part of the outer clasper to the apical part of the same.

No. 2. *Flexor of Outer Clasper.*

This muscle is composed of a few scattered fibres which connect the apical and basal parts of the outer clasper at their junction and is responsible for their grip in the process of mating.

No. 4.

This is a thick spindle-shaped muscle with one end attached to the apodeme of the penis and the other to the ventral median wall of the outer claspers at the insertion of muscle 6. This muscle is probably the retractor of the penis.

No. 5. *Protractor of the penis.*

The thickest muscle of the genitalia, it is spindle-shaped with one end attached to the dorsal median wall of the outer clasper and the other to the apodeme of the penis.

No. 6. *Retractor of the penis.*

From the lateral plate of the penis to the median ventral wall of the outer clasper near the insertion of muscle 4. It is a long muscle of a fair thickness which is situated ventral to muscle 4.

No. 7.

From the inner side of the lateral plate of the penis posterior to the attachment of muscle 6 and anterior to muscle 8, to the lateral wall of the outer clasper. This is a slender muscle situated ventral to muscle 5 and is probably the opener of the penis.

No. 8.

From the outer side of the apical tip of the lateral plate of the penis to the outer clasper. This muscle is composed of a few fibres and is situated above muscles 3 and 10 but ventral to muscle 5 and is inserted on the basal lateral wall of the outer clasper. It may also help muscle 7 in opening the penis.

No. 9.

This is a flat muscle from the lateral plate of the penis to the anterior membranous wall of the penis in the median line. A few of its fibres are also inserted on the ejaculatory duct. Its function may be twofold. The primary one may be to close the penis and thus be antagonistic to muscles 7 and 8. It may also serve to expand the ejaculatory duct and be antagonistic to the circular muscles present in it. The counterpart of this muscle is not described by Snodgrass (1935) or Boulangé (1924).

Nos. 3 and 10. *Flexors of Inner Claspers.*

From the apical part of the inner clasper to the basal lateral wall of the outer clasper. Snodgrass figures only one of these muscles (probably muscle 3), but Boulangé finds both in the form studied by him and states that one of them is antagonistic to the other. The attachments of these two muscles in *Nematus* are similar and so their functions must necessarily be the same. Muscle 3 is thicker than muscle 10 and partly overlaps it. Perhaps this fact led Snodgrass to figure only one of them.

No. 11 (a of Boulangé, 1924).

From the pregenital apophyses of the hypandrium (IX sternum) to the lateral wall of the hypandrium. This muscle appears to be antagonistic to muscle 12.

No. 12 (b of Boulangé).

From the pregenital apophyses of the hypandrium to the lateral wall of the basal ring.

Nos. 11 and 12 are alone involved in torsion.

Boulangé described a third pair of muscles in this connection in the forms studied by him, which he designates c. His muscle c is absent in *Nematus*.

DISCUSSION.

" Torsion."

It is an interesting fact that in the adults of some insects the male copulatory apparatus alone or the copulatory apparatus and the last few segments are present in an asymmetrical condition. Christophers and Edwards (*vide* Lamb) have noted in Diptera, and Boulangé has noted in the Sawflies, that the asymmetry is brought about soon after emergence—a fact which is in complete agreement with my observations on *Nematus.* Recently Richards recorded that in *Calliphora* the twisting occurs at a very early pupal stage. It is probable that further investigations will reveal more such cases. Boulangé noted in the Sawflies studied by him that the inversion may take place in either direction. My observations on *Nematus* confirm this.

Copulation.

The attitude taken by insects before pairing has been designated the " Pose " by Lamb. When they meet tail to tail it is known as " Linear Pose " (L.P.), as distinguished from the " Vertical Pose " (V.P.) where one individual is on the back of the other. In the Linear Pose the dorsal surface of the male tube comes in contact with the dorsal surface of the female vagina. This condition is known as " Direct Correlation." When the male and the female tubes come in contact so that the dorsal surface of one touches the ventral surface of the

other it is known as " Inverse Correlation." From the available data Richards (1927) has shown that in the insects " Inverse Correlation is the general rule."

The attitude adopted by the pair in later stages of copulation is known as the *"position,"* and it is found that in many insects, when once the union has been effected, the male alters his attitude (Richards : 334).

In *Nematus* it has been seen that copulation is preceded by the inversion of the genitalia. Such a condition is also found in some of the Tipulids and Ptychoptera (*vide* Richards), and Boulangé found it to occur in the recorded cases of Sawflies with an inverted genitalia.

There is thus maintained in *N. ribesii* an " Inverse Correlation " with a " Linear Pose." This has been designated the " False Linear Pose " by Richards.

It may be said from all that is known at present that the primitive pose in insects is probably the " Vertical " one. If one considers the subject from an evolutionary point of view the next condition would be when the pair, having started with a " Vertical Pose," adopt a temporary False Linear Pose. This condition is definitely only temporary because the twist the genitalia undergo is only for the copulatory act, returning to normal again after the completion of copulation. This is seen in Trichoptera and many other forms (Richards) and recently has been shown to occur in the cockroach, *Blatta orientalis*, by Qadri (1938). The next stage would be when this condition has been so engrained that before the act of pairing torsion occurred. This condition is represented by the Sawflies, Tipulids and Ptychoptera where the individuals mate end to end in order to maintain " Inverse Correlation." In *N. ribesii* it is seen that the musculature of the outer claspers has been so adapted that their basal and apical parts can bend only in an outward direction. Thus in order to grip the subgenital plate of the female from the outside, which is the most suitable arrangement for a firm hold, they must be in an inverted condition. In this condition the " Vertical Pose " has been discarded and " Inverse Correlation " is still maintained due to the inverted genitalia. The case of *N. ribesii*, where the claspers are very well adapted to perform their function, permits the suggestion that in those insects where False Linear Pose occurs, due to the inverted genitalia, the clasping organs of the males must necessarily be well adapted to the function they have to perform. Finally the Diptera and Coleoptera have reverted to the " Vertical Pose," this being probably due to a want of proper gripping structures in the genitalia. As mentioned before, torsion occurs in them shortly after emergence, or, as Richards has noted in *Calliphora*, it is present in the pupal instar. If such forms mated in a " Vertical Pose " they would adopt " Direct correlation," and this would be contrary to the general rule. In order that " Inverse Correlation " be maintained, the genitalia must necessarily turn in a reverse direction (Detorsion) or be given a further twist in the same direction. The latter alternative is adopted for the simple reason that the musculature, which is already in a twisted condition, offers difficulty for detorsion.

The second question which arises is the manner of migration of the sperms into the spermatheca. Two opinions have been expressed so far. The first, upheld by Adam (1912) and others, states that in the honey-bee it is brought about by a mechanical action on the part of the spermathecal duct which has a muscular arrangement acting as a suction pump. According to the second view the migrations of the sperms is brought about in response to chemical stimuli. Michael (1923) in the silk moth (*Bombyx mori*) found that there is a negative chemotactic substance secreted by the spermatophore cover which, being disagreeable to the sperms, drives them away from it and hence they get into the spermatheca. According to Ritterhaus (1927) there is a positive

chemotactic substance which probably comes from the receptacular glands. Heberdey (1931) rejected the mechanical theory on the ground that if there is a mechanical cause a few sperms should be found in the vagina—which has not been recorded. Furthermore if the source of stimulus came from the receptacular glands, then the sperms must migrate into it—a condition not recorded so far. Finally there are some forms which do not have receptacular glands. The above arguments led Heberdey to assume that there is a positive chemotactic substance secreted by the wall of the spermatheca which is responsible for the migration. The peristaltic contraction of the vaginal and spermathecal walls probably play an auxiliary rôle. Recent observations by Omura (1938) on the silk moth *Bombyx mori* show the presence of no chemical substance. As far as *Nematus* is concerned, the glandular structure inside the spermatheca appears to be a feeding organ, because it shows over activity after the sperms have entered the spermatheca. Furthermore, the receptacular glands which are considered to provide nourishment for the sperms (*vide* Wigglesworth) are absent in this form. The muscles of the spermathecal wall and its duct probably help the sperms to migrate, but it is very likely that the glandular structure in the spermatheca may also be secreting a chemotactic substance. Otherwise it is difficult to explain why at least some of the sperms should not pass into the common oviduct as well. It may be pointed out that the secretion of the male accessory gland is a good medium to convey the sperms. In order to clear this, the problem requires a careful histological and physiological study. This question is therefore left open for future consideration.

Egg Laying.

Morice (1912), who made observations on *Phymatocera aterrima*, stated that the terebrae first pierce the cuticle of the *Polygonatum* stem by successive stabs of the abdomen as a hammer drives a nail, then the saws move backwards and forwards driving it deep in until a pocket is made and finally a rotatory movement lacerates the tissue. The terebrae are then withdrawn and re-inserted and an egg laid. The observations of Chapman (1916) on the same form are not in agreement with those of Morice. According to him the terebrae are driven into the tissue like a pair of scissors by the working of the saws and at no stage in the process are they withdrawn until an egg is laid. His investigations on *Trichiosoma* (1914) and *Pteronidea* (1920) also point to a similar conclusion regarding the working of the saws. In *Nematus ribesii* it has been seen that the saws work alternately and with an up-and-down motion like those of a true saw.

It has been stated by Morice and by Chapman (1920) that the eggs of sawflies derive nourishment from the host-plant. In the eggs of forms such as *Thrinax*, which lie exposed, a vertical incision is made in the host tissue in which the margin of the egg is trapped, thus offering it a larger absorptive surface. How this incision is made Chapman (1920) does not state. In *N. ribesii*, whose eggs are also laid exposed, a similar incision is present which is made by the sheath as the terebrae are dragged back in the process of lowering the egg to the leaf and it is very probable that in *Thrinax* also the vertical incision is made by the action of the sheaths.

SUMMARY.

The male genitalia become inverted shortly after emergence, turning through an angle of 180°. Mating takes place end to end with the two individuals facing opposite directions. The subgenital plate (7th sternum) of the female is gripped by the outer claspers from the outside while the inner claspers press against it from the inside, thus serving an antagonistic function to the outer organs. The penis is inserted deep into the vagina and its valves open wide apart. The sperms are ejaculated in a mass into the vagina along with the secretion from the male accessory gland. Attempts have been made to study the migration of sperms into the spermatheca, where a glandular structure has been seen. It is suggested that this structure is primarily nutritive, but also probably supplies the necessary chemotactic substance.

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THE NUMBERS OF INSECTS CAUGHT IN A LIGHT TRAP AT ROTHAMSTED DURING FOUR YEARS 1933–1937

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DURING the past few years I have published several papers, chiefly in the *Transactions of the Royal Entomological Society of London,* dealing with the analysis of catches of insects in a light trap. Selections from the catches have at times been given but the complete figures have never been published.

It has been suggested that it is desirable to put the whole set of figures on record so that they can be available for anyone wishing to use them for his own interpretation or to support his own theories.

	1933										1934	
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1	31	9	6	15	3,287	424	1,107	483	30	1	0	0
2	208	0	—	134	2,241	3,596	187	112	0	1	11	0
3	—	4	—	224	4,864	1,249	664	77	105	0	2	2
4	—	21	—	406	769	569	167	13	11	2	10	0
5	—	234	34	676	157	262	83	65	68	0	0	0
6	66	351	164	209	1,456	2,500	141	265	382	0	1	0
7	9	22	124	431	295	661	81	910	1,887	0	3	0
8	22	—	43	379	—	371	80	90	420	0	1	0
9	27	125	7	187	63	992	69	17	730	0	0	0
10	6	50	187	313	—	235	59	16	298	0	0	5
11	3	167	97	68	139	192	305	5	37	2	427	7
12	6	26	383	159	93	74	320	22	144	0	9	1
13	2	2	177	400	44	209	112	67	75	0	3	0
14	9	4	50	1,250	51	939	23	65	4	0	4	0
15	11	9	89	1,389	427	179	54	38	36	5	0	0
16	11	88	614	69	262	83	163	0	67	0	9	0
17	5	3	30	14	529	35	161	2	229	17	9	45
18	14	2	88	30	1,505	54	126	39	771	0	0	1
19	—	3	126	63	1,561	159	138	37	84	16	0	1
20	4	5	1,197	165	1,617	20	102	262	58	0	0	1
21	10	8	1,072	98	2,795	21	127	1,326	2,045	8	0	6
22	0	4	5,137	448	2,197	267	118	789	1,483	15	0	4
23	0	2	1,557	396	2,930	35	60	590	45	17	0	0
24	1	101	2,067	1,460	1,533	432	303	710	77	1	0	8
25	—	24	524	714	1,947	420	72	12	3	5	2	7
26	9	13	598	536	5,801	335	411	1	8	165	0	0
27	14	3	122	493	393	740	572	0	166	3	0	0
28	6	90	533	40	170	949	148	147	8	1	6	0
29	23	—	260	2,119	253	1,295	326	57	117	102	0	—
30	0	51	59	229	63	426	342	11	24	7	3	—
31	21	—	23	—	79	301	—	2	—	32	0	—
Total	518	1,421	15,368	13,141	37,521	18,024	6,621	6,230	9,412	500	500	88
No. of days	26	28	28	30	29	31	30	31	30	31	31	28
Mean per day	20	51	549	438	1,294	581	221	201	314	16	16	3·1

The trap was run from the 1st March 1933 to 28th February 1937 and, with the exception of May and June 1936, it only failed to work on 31 nights. During May and June 1936 a special experiment was in progress whereby the trap was only working on two nights out of three, so in each of these two months the trap was set only on 19 nights.

In all the trap was working on 1407 nights and captured a total of just over 853,500 insects. The insects were approximately 87% Diptera, 10% Lepidoptera and 3% of the remaining orders.

	1934										1935	
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1	0	1	21	141	1,345	—	60	413	2	61	1,595	20
2	1	1	20	58	1,059	39	48	227	124	499	2,186	1
3	1	3	11	36	360	61	290	197	16	1,250	266	824
4	2	5	5	146	760	490	176	11	2,089	462	2	112
5	1	7	2	181	273	336	167	15	184	854	12	27
6	3	1	1	110	485	1,556	167	492	11	515	12	3
7	0	4	33	225	573	705	1,319	5,149	7	145	1	2
8	4	28	75	403	687	1,621	326	213	494	20	18	1
9	1	6	34	417	450	174	58	94	126	424	3	2
10	6	0	43	702	417	29	121	323	1,477	185	20	36
11	10	46	191	164	2,042	53	855	961	571	15	4	7
12	4	5	141	36	1,183	153	509	400	33	63	0	11
13	33	3	8	323	858	318	474	109	145	178	184	42
14	3	24	2	2,746	350	217	465	30	1,672	283	473	3
15	0	130	7	317	797	130	527	26	378	664	716	0
16	1	138	7	663	2,164	2,294	232	225	354	146	61	1
17	3	110	5	2,014	2,347	1,936	97	281	340	31	5	6
18	0	3	36	257	573	628	192	487	75	31	4	5
19	2	19	58	88	525	212	272	368	1	234	27	5
20	6	0	15	140	600	63	332	197	3	21	52	4
21	10	58	91	59	2,044	121	7	66	671	5	3	2
22	4	8	1,629	545	2,126	235	3	232	42	2	31	0
23	10	0	127	53	389	92	34	11	686	27	15	—
24	106	2	13	1,074	86	256	23	142	1,974	48	—	—
25	5	2	34	388	488	78	34	31	167	34	—	4
26	12	5	18	319	487	68	23	88	170	92	0	1
27	0	33	53	54	264	144	599	33	1,307	58	0	22
28	1	13	66	145	131	179	1,627	12	964	106	0	53
29	0	4	94	226	314	19	112	9	723	21	27	—
30	0	6	14	1,113	1,046	19	125	7	65	119	32	—
31	3	—	265	—	256	31	—	3	—	21	0	—
Total . .	232	665	3,119	13,143	25,179	12,284	9,274	10,853	14,872	6,613	5,749	1,195
No. of days .	31	30	31	30	31	30	30	31	30	31	29	26
Mean per day	7 5	22	101	438	822	410	309	350	496	213	198	46

	1935										1936	
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1	17	4	8	76	16,797	203	383	53	217	2	691	253
2	81	0	444	47	18,120	2,015	237	319	331	0	74	2
3	72	1	8	50	852	3,633	729	598	3,069	1	12	19
4	5	0	446	95	896	882	171	283	2,128	0	3	0
5	6	0	754	61	7,802	5,417	945	176	326	3	4	2
6	83	53	2,893	44	768	4,508	262	29	26	59	40	0
7	1	64	75	17	392	7,639	50	17	12	7	23	0
8	1	51	51	14	360	8,942	203	9	379	125	114	0
9	0	2	3	295	6,217	435	171	199	11	26	3	0
10	0	0	9	154	15,751	558	258	18	148	4	1	6
11	0	4	13	28	4,836	—	171	14	121	10	9	0
12	0	1	13	252	4,456	524	98	12	2	1	0	0
13	7	61	3	266	3,015	40	136	31	15	131	1	1
14	98	11	22	179	3,277	1,488	409	3,529	12	26	0	3
15	1	15	8	124	2,895	1,849	50	364	49	9	0	1
16	224	4	3	33	464	1,181	21	1,517	46	0	0	1
17	84	3	6	266	820	2,057	54	122	16	0	0	1
18	15	24	6	2,989	56	380	218	18	24	1	0	15
19	1	94	49	530	232	1,122	218	35	29	3	1	1
20	27	17	19	1,043	110	2,309	1,724	6	574	1	0	2
21	292	12	5	1,775	1,819	3,389	714	157	637	1	0	0
22	5	12	4	6,993	9,805	1,376	163	8	82	0	2	24
23	6	54	40	20,170	4,354	2,629	38	866	4	0	1	4
24	120	3	17	23,804	1,410	441	312	225	2	9	1	—
25	2	61	16	4,646	2,533	1,928	56	5	5	14	397	3
26	35	3	35	13,657	1,046	588	723	283	147	19	11	3
27	15	—	924	2,925	590	43	1,658	125	144	85	5	1
28	—	35	599	11,812	2,527	94	4,990	1,288	32	180	53	18
29	15	41	178	11,314	362	172	674	3	16	46	2	0
30	44	10	1,055	73,106	142	3,415	45	317	2	27	49	—
31	101	—	481	—	349	610	—	1,146	—	5	39	—
Total . .	1,358	641	8,192	176,735	113,265	59,888	15,880	11,772	8,603	795	1,539	359
No. of days .	30	29	31	30	31	30	30	31	30	31	31	28
Mean per day	45	22	264	5,891	3,654	1,996	529	360	287	26	50	13

| | 1936 | | | | | | | | | | 1937 | |
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1	0	334	10	25	378	1,248	1,281	1,872	383	27	9	4
2	2	15	—	!	1,176	108	664	26	239	87	21	12
3	4	0	21	42	1,099	33	462	8	388	36	50	28
4	2	0	15	36	726	92	692	—	52	0	0	1,582
5	0	4	—	—	3,288	1,684	249	4	12	0	0	21
6	30	4	174	287	1,144	2,647	252	10	26	1	0	4
7	15	2	223	709	327	3,151	28	67	57	0	1	864
8	33	3	174	—	1,734	843	1,221	32	20	163	0	54
9	91	2	—	400	28	12,996	736	42	213	4	2	0
10	3	6	244	—	265	12,267	2,160	53	—	9	12	—
11	0	1	77	179	82	4,935	461	18	290	0	83	1
12	0	0	—	—	145	3,008	5,989	7	1,193	76	83	8
13	1	4	45	240	55	2,405	689	113	73	2	166	72
14	1	50	—	121	1,500	3,201	586	223	34	—	20	651
15	13	6	174	—	193	6,000	451	174	47	2	2	41
16	1	1	—	325	6,343	9,499	2,406	289	1,357	11	0	8
17	6	0	283	2,277	1,093	6,358	3,026	25	54	18	60	5
18	0	6	—	1,612	146	—	5,284	68	17	55	2	143
19	52	5	101	—	272	2,866	759	27	111	4	1	—
20	52	0	19	4,049	1,492	4,160	2,110	223	4	34	2	25
21	16	1	—	—	1,490	—	330	324	30	21	12	222
22	140	4	129	—	1,801	849	1,355	3,637	4	288	837	0
23	9	12	4	3,203	135	3,483	310	1,755	98	0	20	1
24	4	58	—	3,409	607	6,213	3,060	33	0	5	121	2
25	12	25	391	—	89	10,089	2,009	12	638	—	106	0
26	—	10	—	5,094	113	185	462	20	73	128	1	0
27	5	72	427	—	4,156	183	94	4	22	0	1	0
28	—	203	10	678	2,702	729	33	30	77	14	0	0
29	2	78	—	2,131	1,099	1,645	73	173	267	60	0	—
30	5	4	4	—	1,516	1,895	613	2,001	5	2	20	—
31	133	—	—	—	10,859	3,037	—	58	—	14	87	—
Total . .	632	910	2,525	24,819	46,054	105,309	37,846	11,328	5,768	1,056	1,719	3,848
No. of days .	29	30	19	19	31	29	30	30	29	29	31	26
Mean per day	22	30	133	1,306	1,486	3,631	1,262	378	199	36	55	146

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EXPERIMENTAL STUDIES IN INSECT PARASITISM. VII. THE EFFECTS OF DIFFERENT HOSTS ON THE PARASITE *TRICHO-GRAMMA EVANESCENS* WESTW. (HYM. CHALCIDOIDEA)

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The parasitoid *Trichogramma evanescens* has been reared from more than one hundred different species of hosts. All of those hosts have in common that they are eggs of insects; but they differ greatly in other respects. They belong to six different orders,—Lepidoptera, Diptera, Coleoptera, Hymenoptera, Hemiptera, and Neuroptera. They are the eggs of vegetarian, saprophagous, predacious, and blood-sucking forms. They include large eggs and small; eggs with hard shells and with soft; eggs laid in masses and others laid singly. Among them are eggs that hatch within a few days and others that remain unhatched for several months.

The question must arise whether such widely differing hosts produce parasites that are all exactly alike. The association of *Trichogramma* with its hosts is very intimate. It spends its entire developmental period within them, eating their fluid contents and pupating in their empty shells. The parasite is simply the host transformed. Should not one expect individual parasites to be influenced by the particular hosts in which they have developed?

The purpose of this study is to discover what effects, morphological, physiological, and behaviouristic, are impressed upon *Trichogramma evanescens* by the different hosts in which it can develop to the adult stage. The effects of hosts in which the parasite is unable to complete its development have been considered in an earlier paper of this series (Salt, 1938) and are here of no concern.

All the parasites used in this investigation came from a pure strain of *Trichogramma evanescens* descended from a single female parent and reared now for more than 260 generations exclusively on eggs of the grain moth, *Sitotroga cerealella* (Oliv.). Except where it is otherwise stated, all the experiments were carried out at 25° C. and 80% relative humidity.

MORPHOLOGICAL EFFECTS.

1. *Effects on the size of the parasite.*

The most marked effect of different hosts on *Trichogramma evanescens* is their influence on the size of the parasite. A simple demonstration of this effect is provided by the following experiment. From a large collection of eggs of *Sitotroga cerealella*, ten of the smallest were selected; and from a similar lot of eggs of *Ephestia kuehniella* Zell., ten of the largest. A female parasite from a pure strain reared on *Sitotroga* was allowed to lay in three of the small *Sitotroga* eggs, then in three of the large *Ephestia* eggs, and finally in two or three eggs of *Agrotis c-nigrum* (L.). The hosts and the parasites that emerged from

them were measured. The experiment was repeated fifteen times. The influence of the largest host, *Agrotis*, is obscured by the fact that, while only a single parasite emerged from each egg of *Sitotroga* and *Ephestia*, in only four cases was there a solitary emergent from the eggs of *Agrotis*, which usually yielded two parasites. Nevertheless, the results, arranged in Table I, show that there

TABLE I.

Average size in mm./10 of individuals of *Trichogramma evanescens* reared from three different species of hosts.

		Number measured	Size of parasite				Size of host	
			Length	Width of			Length	Diam.
				head	thorax	abdomen		
Parents		15	4·1	1·8	1·4	1·5	5·5	2·4
Female progeny from	Sitotroga . .	21	3·9	1·7	1·4	1·4	4·4	2·3
	Ephestia . .	32	4·7	2·1	1·7	1·7	5·7	3·6
	Agrotis . .	32	5·1	2·4	1·9	2·1	5·6	6·5
	Agrotis (solitary)	3	5·7	2·7	2·1	2·5	5·6	6·5
Male progeny from	Sitotroga . .	17	4·0	1·8	1·5	1·3	4·4	2·3
	Ephestia . .	8	4·6	2·1	1·7	1·6	5·7	3·6
	Agrotis . .	17	5·1	2·4	1·9	1·9	5·6	6·5
	Agrotis (solitary)	1	5·9	2·8	2·2	2·2	5·6	6·5

is a close correlation between the size of the different species of hosts and that of the parasites that emerge from them.

A table giving the average result, however, fails to show the great range of size that may occur among the progeny of a single parasite when it attacks different hosts. In a particular case, illustrated by figure 1, the parent measured 0·40 mm. in length; her smallest female offspring, from *Sitotroga*, 0·34 mm.; each of her three female progeny from *Ephestia* 0·46 mm.; and her largest offspring, a solitary female from an egg of *Agrotis*, 0·57 mm. These measurements represent the greatest range obtained in the particular set of experiments described, but they are far from indicating the limits of size of *Trichogramma evanescens*. In the course of other work, individuals descended from the pure strain have ranged in length from 0·24 mm. to 0·7 mm. Hase (1925 : 200) obtained a maximum length of 0·9 mm. in the same species.

The preceding experiments show that the size of *Trichogramma* is influenced by different species of hosts. Within a more limited range, the size of the parasite is also affected by large and small individuals of a particular host species. *Sitotroga cerealella* is a suitable host for a demonstration of this fact because examples can be visually selected so different in size that the largest are nearly twice the volume of the smallest. Experiments were conducted as follows. From a collection of fresh eggs of *Sitotroga*, nine large and nine small ones were chosen and were placed in two groups, each of which could be covered by a small glass container ¾ inch in diameter and ¼ inch deep. A female *Trichogramma* was placed on the group of small eggs and left for 3 hours at

25° C.   The parasite was then transferred to the group of large hosts for one hour.   On the fifth day, those small eggs which had turned black, and an equal number of black large eggs, were first measured and then isolated in small vials so that the parasite emerging from each should be known.   A few hours after their emergence, the parasite progeny were asphyxiated and measured.

Parent

Hosts

Sitotroga   Ephestia   Agrotis
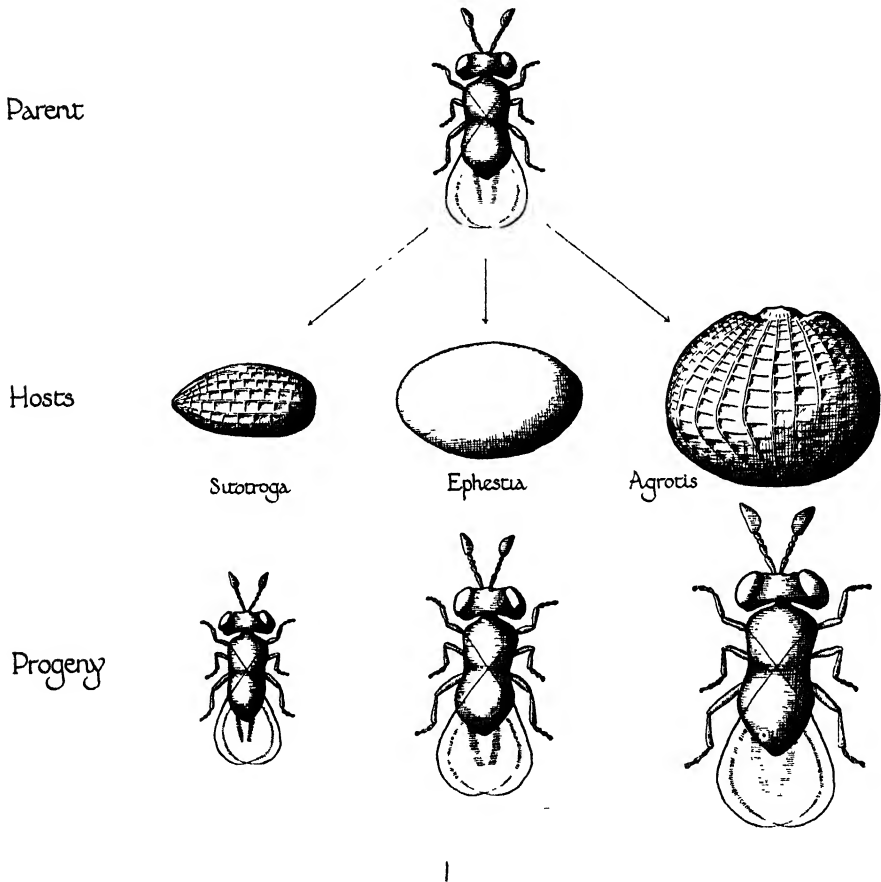
Progeny

FIG. 1.—Relative size of a female *Trichogramma evanescens* and three female progeny reared from different species of hosts.

The experiment was repeated 15 times but, owing to the reluctance of the parasites to attack very small hosts (see page 92 below), only 18 of the 135 small hosts exposed were parasitised and only 11 gave emergent parasites. The measurements of each of these 11 parasites and their hosts, together with those of an equal number of emergents from large eggs from the same experiments, are set out in Table II.   It is clear that the larger hosts produced larger parasites than smaller hosts of the same species.

TABLE II.

Measurements in mm./10 of large and small eggs of *Sitotroga cerealella* and of the individuals of *Trichogramma evanescens* that emerged from them.

Selected small hosts							Selected large hosts						
Hosts		Parasites					Hosts		Parasites				
			Width of							Width of			
Length	Diam.	Length	head	thorax	abdomen	Sex	Length	Diam.	Length	head	thorax	abdomen	Sex
4·2	2·1	3·6	1·8	1·3	1·3	♂	5·4	2 5	4·4	1·8	1·4	1·4	♂
4·4	2·5	4·0	1·8	1·4	1·4	,,	5·8	2·4	4·8	1·9	1·5	1·6	,,
5·0	2·2	4·0	1 8	1·4	1·3	,,	6·2	2·4	4·8	1·9	1·5	1·6	,,
4·5	2·3	4·1	1·7	1·3	1·4	♀	5·8	2·4	4·7	1·9	1·4	1·6	♀
4·7	2·1	3·8	1·7	1·3	1·3	,,	5·8	2·5	4·8	2·0	1·4	1·6	,,
4·7	2·1	4·2	1·6	1·3	1·4	,,	6·0	2·3	4·9	2·0	1·5	1·7	,,
4·8	2·2	4·0	1·7	1·3	1·4	,,	6·0	2·4	4·8	1·8	1·5	1·6	,,
4·9	2·0	4·2	1·7	1·3	1·4	,,	6·0	2 5	4·8	1·9	1·5	1·7	,,
5·0	2·1	4·0	1·7	1·3	1·4	,,	6·0	2·5	4·9	2·0	1·6	1·7	,,
5·0	2·2	4·0	1·7	1·3	1·4	,,	6·0	2·5	4·9	2·0	1·6	1·7	,,
5·2	2·3	4·0	1·6	1·3	1·5	,,	6·2	2 4	4·8	2·0	1·5	1·7	,,
4·8	2·2	4·0	1·7	1·3	1·4		5·9	2·4	4·8	1·9	1·5	1·6	

The eggs of any particular species of host do not range very widely in size, so that solitary parasites from any one species of host are not very different. But eggs of one species of host can produce parasites of very different dimensions if the parasites are not solitary but gregarious. *Trichogramma evanescens* is facultatively gregarious and so permits the following experiment. Into each of two petri dishes were put 50 eggs of *Agrotis c-nigrum*. Ten female parasites were introduced into one dish and 75 into the other, and the dishes were put into an incubator at 25° C. After four hours, the parasites were removed and each of the 100 hosts was isolated in a small vial. On the tenth and succeeding days, the parasite progeny emerged; two or three out of each host from the first dish; four, five, or more out of each host from the second dish, where the density of parasites had led to superparasitism. The emergents were allowed a few hours in which to dry and harden their integument, and were then asphyxiated and immediately measured. The measurements are arranged in Table III, which shows that as the number of gregarious parasites per host increases, the size of the individual parasites is diminished.

It is in cases of superparasitism such as those in the lower part of Table III, where 6 or 7 parasites shared a single host, that the degenerate forms called " runts " appear. These tiny, feeble individuals (fig. 2) occur with increasing frequency as the intensity of parasitism rises. In the experiment described above, no runts emerged from hosts containing two, three, or four parasites; but 4 came from eggs containing five, 7 from eggs containing six, and 12 from eggs containing seven parasites. There can be no doubt, as I shall show later, that runts are produced as a consequence of starvation. Theoretically a solitary runt should emerge from a host that is just too small to support a fully developed parasite. Practically, however, they are seldom if ever produced in this way, for the simple reason that females of *Trichogramma*

TABLE III.

Average size in mm./10 of gregarious individuals of *Trichogramma evanescens* reared from eggs of *Agrotis c-nigrum*.

Number of parasites per host	Size of parasite				Number of parasites measured
	Length	Width of			
		head	thorax	abdomen	
2	4·8	2·4	1·7	1·9	20
3	4·2	2·1	1·5	1·6	15
4	3·9	1·9	1·4	1·5	16
5	3·6	1·7	1·2	1·3	40
6	3·2	1·6	1·2	1·3	18
7	3·1	1·6	1·2	1·2	28

will not lay in such small hosts; and it is only when a host of adequate size is superparasitised that these abnormal individuals appear. Runts represent the ultimate effect on the adult parasite of hosts of too small a size.

2. *Effects associated with size.*

In the foregoing paragraphs a positive correlation has been established between the size of the host and that of its parasite. It follows that any character, whether morphological, physiological, or behaviouristic, that is connected with the size of the parasite must be considered in this paper, because it may be influenced by the host. The physiological and behaviouristic characters will be considered in their places below.

Most of the morphological characters correlated with size in *Trichogramma* have to do with the proportions of the limbs and of the various parts of the body. The influence of the host on these is proportional to its influence on gross size, and the effects are so self-evident as to need no particular study. There are one or two effects, however, that are less obviously a matter of stature and that are worthy of brief mention.

(a) *Trichiation of the wings.*

The wings of *Trichogramma* are adorned with numerous hairs, of which the larger, or macrotrichia, are arranged in nine principal rows. The effect of different hosts on the number of macrotrichia in these rows has been studied by Oldroyd and Ribbands (1936), using my pure strain of *Trichogramma evanescens* and its F_1 progeny reared from the eggs of several Lepidoptera. These workers have demonstrated a very close correlation between the number of macrotrichia in the rows and the length of the wing (their figure 2), and have shown that both of these are positively correlated with the size of the host from which the parasite emerged.

(b) *Hairiness of the male antennae.*

The flagellum of the antennae of the male *Trichogramma evanescens* bears numerous long hairs which are a conspicuous characteristic of the sex. The length of these hairs remains relatively constant, being always greater than that of the scape, but the number varies with the size of the animal. Ten

antennae of males reared from *Sitotroga* were found to have an average of
about 30 long hairs, while the antennae of larger males reared from *Agrotis*
had an average of 37 hairs.

2
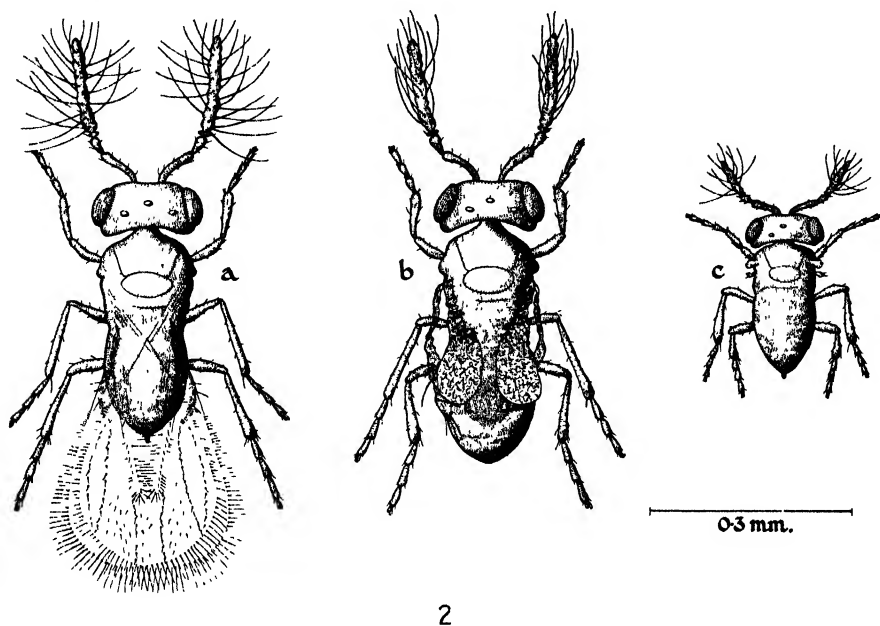
Fɪɢ. 2.—*Trichogramma evanescens* Westwood. A, normal male; B, normal male just
    emerged, with the wings unexpanded, the antennal hairs appressed, and the meconium
    not yet cast; c, male runt.

3.   *Effects apart from size.*

In *Trichogramma evanescens* there are apparently no morphological effects
of the host upon the parasite apart from those associated with size.   In a
related species, *Trichogramma semblidis* (Auriv.), it has recently been shown
that one particular host, *Sialis lutaria* (Fab.), has the peculiar effect of eliciting
a normal apterous form of the male, quite different in several characters from
the ordinary winged male (Salt, 1937).   Eggs of *Sialis lutaria* had not that effect
on the few individuals of *T. evanescens* that were successfully reared from them
(Salt, 1939), and no similar apterous form of *T. evanescens* has ever been
proved to exist.

This has to be emphasised because several authors have in the past referred
to apterous males of *T. evanescens*.   It appears, however, that they had either
confused the two species, *evanescens* and *semblidis*; or had not given the
newly emerged parasites time to expand their wings (fig. 2, B); or else had
looked upon the runts of *evanescens* as the equivalent of the apterous forms of
semblidis.   But runts are not at all normal forms.   Four considerations in-
dicate that they are degenerate individuals produced by starvation.   They do
not occur in uncrowded cultures but are always associated with superpara-
sitism.   They are invariably very small (0·24 to 0·33 mm. long).   They are so
feeble that they live only a few hours and are never able to move actively or,

so far as I have observed, to reproduce. All the structural peculiarities that have been ascribed to them (reduction or loss of wings, changes in the antennae) are characters of degeneration and distortion (fig. 2, c). The formation of runts is, indeed, the most striking effect of the host on the structure of *Trichogramma evanescens*, but it is not the appearance of a new apterous form. It is merely the final stage of the reduction in size of the parasite under the influence of an insufficient host.
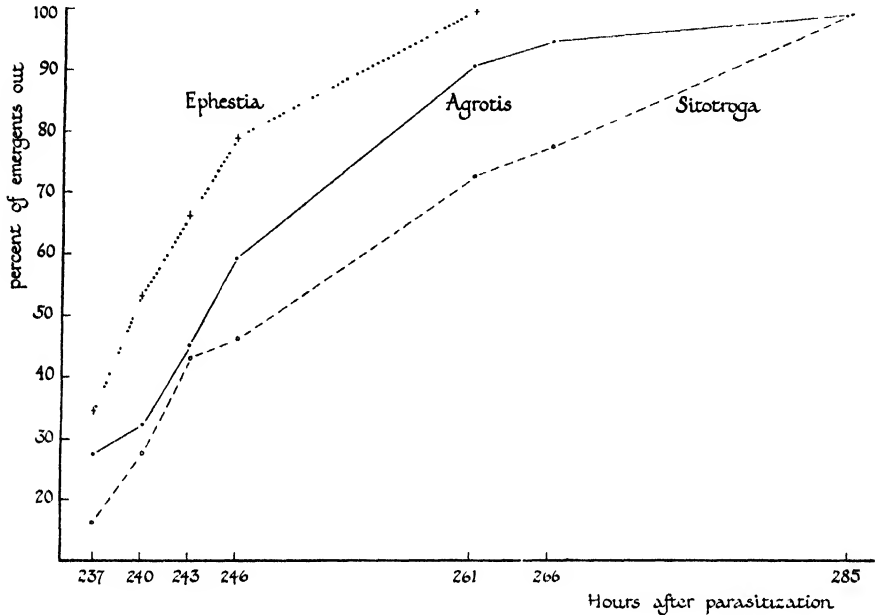
3

FIG. 3.—Relative time of emergence of individuals of *Trichogramma evanescens* reared on three species of hosts.

PHYSIOLOGICAL EFFECTS.

1. *Effects on the rate of development.*

The influence of temperature and other physical environmental factors on the rate of development of insects is now thoroughly appreciated, but the effects of biotic factors are only just beginning to be realised. In the case of parasites, the host is one of the environmental factors that must be considered. This is demonstrated by observations made in the course of the experiment described on page 81. In that experiment, the progeny of 15 females of *Trichogramma evanescens* were reared on three species of hosts, *Sitotroga*, *Ephestia*, and *Agrotis*. The time of parasitisation was known within a few minutes; the parasitised hosts were kept together under identical and controlled environmental conditions; and the time of emergence of the parasites was recorded. The earliest progeny appeared 236 hours and the latest 285 hours after parasitisation. In eggs of *Ephestia* the average developmental period was 243 hours; in *Agrotis* 250 hours; and in *Sitotroga* 256 hours. When the emergence of the parasites from these three hosts is plotted against time

(fig. 3), it is apparent that the parasites emerged from eggs of *Ephestia* earlier than they did from eggs of either *Agrotis* or *Sitotroga*.

The reason for this has not been deliberately investigated, but several observations suggest that two factors may be concerned : (1) Eggs of *Ephestia* have a thinner chorion than those of either *Sitotroga* or *Agrotis* so that the young adults may be able to bite a way out of them more easily.   (2) *Ephestia* eggs may provide the optimum amount of food for rapid emergence, while *Sitotroga* eggs provide too little and *Agrotis* eggs too much.   That there is such an optimum is suggested by the fact that solitary individuals in *Agrotis* required an average of 262 hours to emerge; individuals sharing *Agrotis* eggs in twos required 247 hours; and individuals sharing them in threes emerged in only 244 hours.

Eggs of *Galleria mellonella* (L.) seem to delay the emergence of *Trichogramma* very noticeably.   On the one occasion when I was able to use this species as host, many of the parasitised eggs did not blacken until the 6th, 7th and 8th days after parasitisation, and the parasite progeny emerged on the 13th and 14th days, although *Ephestia* eggs attacked at the same time and kept beside them in the same dish turned black on the 4th and 5th days and yielded their emergents normally on the 10th day.

The foregoing paragraphs show that certain hosts are capable, within rather small limits, of influencing the rate of development of *Trichogramma evanescens*.   The principal interest in this subject, however, naturally lies in the much greater effect that might be produced by hosts in diapause.   Marchal (1936) has shown that when *Trichogramma cacaeciae* March. is reared on eggs of *Cacoecia rosana* (L.) while they are in a diapause, its development is inhibited for a period of seven months, but, if it is reared on eggs of *Ephestia* or on eggs of *Cacoecia* that are not in a state of diapause, it goes on developing at a rapid rate.   This is a matter of considerable interest and is also of practical importance because, if hosts could be found that would induce a diapause in *Trichogramma evanescens*, shipment of the parasite to various parts of the world for the practice of biological control would be rendered easy.   The problem has therefore been studied during two seasons, using as hosts the following species of Lepidoptera.

(a) *Polia flavicincta* (Fab.).

The eggs are laid in August and September and hatch the following April. They are yellow when laid but turn brown during the first few days owing to the formation, inside the colourless chorion, of a dark membrane (the serosa) which surrounds the yellow yolk.   This process is complete on the fifth day and then, as shown by weekly dissections, the egg remains without further development during the winter.   That the eggs are actually in a state of diapause is indicated by the fact that whether they are kept during the autumn and winter at natural temperatures or at a constant temperature of 25° C., they do not hatch until the spring.

For experiments on parasitism, the eggs of a fertile clutch were divided into nine groups.   One group was exposed to parasitisation on the day the eggs were laid, and succeeding groups when they were 7, 14, 21, 28, 35, 39, and 46 days old.   The eggs were readily parasitised and in every case the parasite progeny developed at once and emerged normally 10 or 11 days after parasitisation.   The ninth group, which was unparasitised, hatched the following spring.   The eggs of *Polia flavicincta*, then, although themselves in a diapause, did not induce a diapause in the parasite *Trichogramma evanescens*.

It may be mentioned in passing, that eggs laid by an unmated *Polia* female, which were infertile and therefore never would have hatched, were successfully parasitised and yielded emergent parasites at the normal time.

(b) *Epineuronia popularis* (Fab.).

The eggs of this species are laid in September and hatch in the following spring, so that its habit appears similar to that of *Polia*. The similarity is only superficial. The embryo of *Epineuronia* develops rapidly, so that 14 days after the egg was laid the larva is almost fully formed, and after 28 days the larva is completely developed and can move within the egg-shell. Kept during the winter at 25° C., a number of these larvae never emerged and eventually died, but others kept at natural temperatures hatched the following March. *Epineuronia*, therefore, passes the winter in a true diapause which is apparently of the egg but actually of the first-instar larva within the egg-shell.

Eggs of *Epineuronia* were parasitised on the day they were laid and others at 19 days of age, and both groups yielded parasite progeny after 10 days. It may be claimed, however, that these hosts were still developing and therefore not yet in their diapause. Other hosts, however, were exposed on the 32nd day when the host larvae were fully formed and presumably in a state of diapause, and a single parasite progeny emerged 11 days later. It is unfortunate that there were not more emergents from this experiment, but the female parasites were disturbed in the act of laying by the movements of the fully developed host larvae inside the eggs (*cf.* Salt, 1938 : 236) and in most cases they withdrew immediately after penetrating the egg-shell and went off without actually parasitising the host. No additional parasites emerged the following spring; and it is certain, at any rate, that no diapause was induced in *Trichogramma* by this host.

(c) *Xanthorhoe didymata* (L.).

This species is said to pass the winter in the egg stage. A few eggs laid on 9th August contained fully developed larvae when dissected on 12th September; so that, if the statement is true, there must be a diapause of the first-instar larva, as in *Epineuronia*. Some of the eggs were exposed to *Trichogramma* on 31st August and yielded parasite progeny on 14th September.

(d) *Orthosia gilvago* (Esper).

This late-flying noctuid is supposed to hibernate in the egg stage. Eggs laid on 21st October and kept at room temperature during the winter shrivelled and never hatched. Eggs of the same clutch exposed to *Trichogramma* on the day they were laid and then kept at 25° C. gave parasite progeny on the 10th day.

It would obviously have been desirable to rear *Trichogramma evanescens* on *Cacoecia rosana* in order to discover whether that host has the effect on the parasite that it has on *T. cacaeciae*. Unfortunately, in spite of attempts extending over two seasons, I have never been able to experiment with eggs of *C. rosana*. Marchal (1936 : 516–19) says that his strain of *T. evanescens* would not attack eggs of *Cacoecia* in diapause, and that when it attacked fresh eggs, no progeny developed.

No host, then, has yet been found which induces a diapause in *Trichogramma evanescens* as *Cacoecia rosana* does in *T. cacaeciae*. This matter is discussed below.

2. *Effects on vigour.*

Large individuals of *Trichogramma* appear stronger and more vigorous than small specimens. In order to translate this appearance into objective data, it is necessary to measure the rate at which some physical activity is performed. Rate of movement would serve; but a more convenient activity for measurement is that of oviposition. It has been shown elsewhere (Salt, 1938 : 224) that the shells of some hosts offer considerable resistance to the ovipositor of the parasite, and are pierced only after arduous drilling that lasts for several minutes. The time required to drill through the chorion of the host, therefore, will serve as an indication of the strength of the parasite.

Experiments to measure the strength of parasites reared from different hosts were performed as follows. A female parasite was first allowed to attack two eggs of *Sitotroga*, since young females do not always drill efficiently on their first host. They were then presented successively with four different species of hosts—*Sitotroga cerealella, Ephestia kuehniella, Agrotis pronuba* (L.), and *Hydriomena bilineata* (L.), in that order—and were allowed to attack two of each of them. Each attack was observed under a binocular-dissecting microscope and the time between its beginning and the penetration of the host, that is, the total time occupied in drilling through the chorion, was measured with a stop-watch. Immediately after completing its series of ovipositions, the female was asphyxiated and measured. The experiment was repeated fifteen times, five times with small females emerged from eggs of *Sitotroga*, five times with middle-sized parasites from eggs of *Ephestia*, and five times with large females from eggs of *Barathra brassicae* (L.). The results, summarised in Table IV, show clearly that the time required to penetrate the chorion of the host varied inversely with the size of the parasite. One may say, then, that the large females emerged from *Barathra* were stronger than those from *Ephestia* and these latter than the small females reared from *Sitotroga*.

TABLE IV.

The average time required by parasites from three different hosts to drill through the chorion of four species of host eggs.

(Each time quoted is the average of ten observations.)

Parasite from			*Sitotroga*	*Ephestia*	*Barathra*
Average length in mm./10	.	. .	4·2	4·7	5·2
Time required to drill through	*Sitotroga*	. . .	1′ 14″	1′ 1″	50″
	Ephestia	. . .	44″	36″	32″
	Agrotis .	. . .	1′ 34″	1′ 31″	1′ 2″
	Hydriomena .	. .	13′ 52″	10′ 30″	7′ 14″

The time required to pierce the chorion of a host is a test of the strength of a parasite. The time required to perform a succession of such acts will serve as an indication of its vigour. During the last few years many experiments have been performed in which females of *Trichogramma* were allowed to oviposit in a number of hosts under observation, the time of each act being carefully recorded. From the notes of such experiments as are comparable for my present purpose, it appears that small parasites, emerged from eggs of *Sitotroga*, required an average of 66 minutes to find, examine, penetrate, and parasitise

10 hosts; while large parasites, emerged from eggs of *Agrotis*, required only 37 minutes. These experiments were not designed as a demonstration of vigour but they serve to indicate what is readily apparent to an observer, that large parasites are much more vigorous than small ones in the various movements involved in seeking and parasitising hosts.

That the host affects the strength and vigour of its parasite through the effect on size is clear. It must not be assumed, however, that the host affects the physiology of its parasite *only* through the effect on size. Some hosts produce quite large parasites which are nevertheless extremely feeble. The few individuals of *Trichogramma evanescens* that have been reared from eggs of *Sialis lutaria*, for instance, were of good size, but they were very weak and inactive. They moved slowly, rested often, and, whether through weakness or disinclination, did not attack any hosts. *Sialis lutaria*, however, is a host normally unsuitable for *Trichogramma evanescens* (Salt, 1938 : 231) so that the problem merges at this point into that of Host Suitability and passes out of the scope of the present paper.

3. *Effects on longevity and fecundity.*

The weakness of specimens of *Trichogramma evanescens* reared from eggs of *Sialis lutaria* has been mentioned. These individuals were not only feeble, they were also very short-lived. Of the 20 that were reared from that host, 17 died within 12 hours of emergence and only one lived longer than a day. None of them was able to reproduce. It may be said, therefore, that the host can directly affect the longevity and fecundity of its parasite.

The host can also affect fecundity through the effect on size. Flanders (1935 : 177) says that large specimens of *Trichogramma* (? species) may be over five times as prolific as small ones. Published data (Salt, 1935 : 417) show that individuals of *T. evanescens* reared from *Ephestia* laid more eggs in an 8-hour period than did the smaller individuals reared from *Sitotroga*; and unpublished experiments indicate that large parasites from eggs of *Agrotis* have a much higher reproductive rate.

As for longevity, the adults of *Trichogramma* that in my experience have lived longest were a number of large specimens emerged from eggs of *Agrotis*.

It was my intention to include here mortality curves and data on fecundity for parasites of different sizes, but circumstances have prohibited the experiments that were planned for this part of the paper.

BEHAVIOURISTIC EFFECTS.

The host from which a female *Trichogramma* emerges does not appear to condition the parasite to seek hosts of the same species for its progeny. This fact was first pointed out by Hase (1925 : 186), who allowed females of *Trichogramma evanescens* reared from various insect eggs to choose hosts for their progeny, and found that they showed no preference for the species from which they had themselves emerged. It has since been shown (Salt, 1935 : 417) that a pure strain of *T. evanescens* reared for 63 generations exclusively on eggs of *Sitotroga* did not develop in that time a preference for its accustomed host but, when given the choice, still preferred to attack eggs of *Ephestia*. Recent experiments show that this pure strain still chooses eggs of *Ephestia* or *Agrotis* in preference to those of *Sitotroga* although it has now for more than 260 generations had experience of no host other than *Sitotroga cerealella*.

Nevertheless, the host does influence the selective behaviour of its parasite, although only indirectly, through the effect on size. In a previous paper of this series (Salt, 1935) it was demonstrated that the size of the host is an important factor in determining its acceptability to *Trichogramma evanescens*. Among additional data now accumulated on this subject, but not yet published, one is of particular concern here. It is, that the minimal size of host acceptable to a parasite depends upon the size of the parasite itself. Large parasites do not accept hosts that smaller parasites will readily attack.

Three types of experiments illustrate this fact. In the first type, a large female emerged from an egg of *Agrotis* was placed in a dish with 30 small eggs of *Sitotroga*, and was kept under observation. The parasite was eager to lay and passed from egg to egg, giving each a cursory examination, but almost immediately rejecting it. After a time the parasite lost interest in the small hosts, and moved away from them towards the sides of the dish but, by manipulation of the dish with regard to light and gravity, it could be led to them again. After half an hour, every egg had been found at least once; but none had been accepted or had even evoked a careful examination. The parasite was then removed to a dish of *Agrotis* eggs. The first it met attracted its complete attention, and was accepted; proving that the female was eager to lay. The parasite was allowed to oviposit in 3 or 4 eggs of *Agrotis* and was then put back for a quarter of an hour into the dish of small *Sitotroga* eggs, which it again refused to attack. This experiment was repeated four times with identical results. The four large parasites did not accept a single small host.

In the second type of experiment, two dishes were prepared, each containing 25 small eggs of *Sitotroga*. Into one was placed a female *Trichogramma* emerged from *Sitotroga*; into the other, one reared from an egg of *Agrotis*. The dishes were put into an incubator at 25° C. for $4\frac{1}{2}$ hours. The parasites were then removed and the dishes left in the incubator to develop. This experiment was repeated four times. Each of the small parasites from *Sitotroga* eggs accepted and parasitised some of the small hosts, 9, 17, 18, and 20 being parasitised in the four experiments. Only one of the larger females (an individual measuring 0·49 mm. in length) attacked the eggs, parasitising 14 of them. The other three large females did not parasitise any.

In both of the above groups of experiments, the parasite was left with the hosts for only a part of its life. In other experiments a large female reared from *Agrotis* was placed in a dish with 50 small *Sitotroga* eggs, and left at 25° C. until it died, about 36 hours later. This experiment also was repeated four times. One female (0·48 mm. long) parasitised four of the small hosts; the other three parasitised none.

The twelve experiments described are supported by many others of different types. One has been mentioned above (p. 83); Laing (1938 : 296) has recorded another; and Flanders (1935 : 177) has published a similar observation on the American *Trichogramma* that is sometimes called *T. evanescens*. All these observations lead to the same conclusion—that large females of *Trichogramma* usually fail to attack hosts of small size although the latter, which are readily parasitised by smaller individuals, are actually suitable for their progeny.

It follows from all these data that the host, through its effect on the size of its parasite, affects the behaviour of that parasite in regard to the size of the hosts that it, in its turn, will parasitise.

DISCUSSION.

In one sense, this study is a continuation of the preceding paper of this series (1938) dealing with the problem of Host Suitability. In that paper were considered the properties of the host that influence the parasite during its immature stages. It was there observed that some hosts (considered, from the point of view of the parasite, as unsuitable) so affect the young parasites feeding upon them as to prevent their development. In this paper have been considered the properties of the host that influence the parasite in its adult stage. I have here observed that some hosts, although they are themselves destroyed, may affect the adult parasites that emerge from their remains.

The object of this study has been to discover in what characters and to what extent different hosts can influence adults of *Trichogramma evanescens* that have developed upon them. In some respects the search has been disappointing. In a related species, *Trichogramma semblidis*, one host, *Sialis*, so deeply influences the parasite as to alter completely the facies of its male sex (Salt, 1937). In another species, *T. cacaeciae*, the host *Cacoecia rosana* so seriously affects the development of the parasite as to delay its emergence for seven or eight months (Marchal, 1936). No such striking effect of a host has been found in *T. evanescens*.

Two explanations are possible. It may be that only certain hosts have the quality of eliciting a reaction in *Trichogramma evanescens*, as only *Sialis* alters *T. semblidis* and only *Cacoecia* affects *T. cacaeciae*. In that case, a continued search might ultimately reveal a host which would induce a dimorphic form or a diapause or some other striking effect in *T. evanescens*. On the other hand, it may be that the ability to develop a distinct apterous form in *Sialis* is a specific character of *T. semblidis* and the capacity to be influenced to enter a diapause a specific character of *T. cacaeciae*; "specific" in both cases being understood to mean "distinct from *T. evanescens*." In this case, no host can have the effect on *T. evanescens* that *Sialis* and *Cacoecia* have on their parasites.

The principal effects that different hosts have been found to have on *Trichogramma evanescens* are those concerned with size. This is a rather obvious result. The host is the food of the parasite. According as it is well fed by an ample host or starved by a meagre one, *Trichogramma* is large or small. But it is not merely the stature of the individual that is affected. So far as they are correlated with its size, the physiology and the behaviour of the parasite are also influenced by the host.

Indeed, one of the effects correlated with size—the selection behaviour of the parasite—is perhaps the most interesting that has been found in *Trichogramma evanescens*. I have shown that large parasites emerging from large hosts tend in their turn to parasitise only large hosts, and disdain to attack small hosts that would actually be suitable for their progeny. Small parasites, for their part, have difficulty in piercing the chorion of large hosts and are sometimes quite unable to penetrate them (Salt, 1938 : 225). In effect, these two results tend towards a division of the species into two ethologically isolated strains : one of large individuals unwilling to attack small eggs, and one of small individuals unable to parasitise large ones. Such a difference might in some circumstances be expected to lead to the separation of two distinct forms. Ordinarily, however, two factors oppose that result—the tendency of small females to prefer large hosts and stubbornly to attack them (Salt, 1935), and the habit of large females of laying several eggs in a large host so that the size

of their gregarious progeny is much reduced (p. 84 above). These two factors ordinarily prevent the complete segregation of the two strains.

A general consideration of the results of this study raises a matter of fundamental importance. The possibility of progress in quantitative biology depends on the existence of biological constants which, although not necessarily so precise as those of physics and chemistry, are characteristic of particular species. The fecundity of an organism, for instance, is usually considered to be a biological constant. That a litter of kittens should number between 3 and 6 is taken for granted; and there would be consternation at home if the family cat suddenly produced a litter of 250, the average number of young produced at one time by many flies. But I have found that the number of eggs a female *Trichogramma* can lay depends to a very considerable extent on the host from which it emerged. The concept of biological constants seems to be put into doubt by such a study as this, in which not only the fecundity but also many points in the morphology, physiology, and behaviour of an animal species is found to be influenced by a factor, the host, that has already ceased to exist when the observations are made.

The difficulty will be resolved when it is thoroughly understood that the fecundity, for instance, of an organism is not precisely stated by a bare number. A flour moth (*Ephestia kuehniella*, Payne, 1934) may lay 225 eggs at 27° C.; but only 177 at 20° C. under otherwise identical conditions. A fruit-fly (*Drosophila melanogaster*, Pearl, 1932) may lay 12·6 eggs per day when it is in a bottle with one other fly; but only 8·5 eggs per day when it is in an identical bottle with three other flies. To define the boiling-point of a fluid, a physical constant, the physicist must record the pressure at which his observation was made. Similarly, to define the fecundity of an organism, a biological constant, it is essential to record in considerable detail the environmental conditions, physical and biotic, under which it was determined. In many cases one does not even know which of those conditions are important. This study shows that in the case of *Trichogramma*, and probably of other parasitoids, the host is one of the effective factors that must be controlled and stated before biological constants relating to the parasite can have any general validity.

SUMMARY.

(1) The size of individuals of *Trichogramma evanescens* is largely controlled by the size of the hosts in which they develop.

(2) The vigour, the fecundity, the longevity, and the rate of development of individuals of *Trichogramma* are affected by their hosts.

(3) Through its effect on their size, the host influences the behaviour of females of *Trichogramma* selecting hosts for their progeny.

(4) The host is one of the environmental factors that must be controlled in any quantitative work on *Trichogramma*.

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BOOK NOTICE.

Insect pests in stored products. By H. HAYHURST. Photographs by H. BRITTEN. 8vo. London (Chapman and Hall), 1940. pp. 83, 49 pls. Price 15s.

This book consists of a series of articles originally published in *Food* from August 1939 under the title " Insect infestation of stored products."

It comprises a list of Insect and Arachnid pests of stored products with some account of control measures. Lists of the products on which each pest has been recorded are given and a description of the larval and adult stage of each pest with an illustration of most of the species.

The book is written " in such a way that any technical man without much entomological knowledge can readily understand and follow it." It is addressed to " those engaged in the transport, the manufacture, the wholesaling and storing of perishable goods, and particularly, of course, of food-stuffs."

BOOK NOTICE.

A Survey of insecticide materials of vegetable origin. Edited by H. J. HOLMAN. pp. viii + 155. 8vo. London (Imperial Institute), 1940. Price 3s. 6d.

This work is issued, under the auspices of the consultative committee on insecticide materials of vegetable origin, by the Plant and Animal Products Department of the Imperial Institute.

The book is arranged in 5 parts dealing with: Alkaloid-containing materials; Plants containing Rotenone and allied compounds; Pyrethrum; Quassia; and Plant oils.

The scope of the book is not restricted to empire sources but the whole of the existing, and in some cases the potential, world sources are surveyed.

The list of references to the literature which is given in the book extends to 372 titles. There is no index to the book but a full table of contents is supplied.

THE REPRODUCTIVE ORGANS OF *SCATOPHILA UNICORNIS* CZERNY (DIPTERA)

By Niels BOLWIG, M.Sc., F.R.E.S.

I GIVE here a short description of the reproductive organs of the fly *Scatophila unicornis* Czerny. The study was carried out by simple dissection under a binocular microscope, all the diagrams being made with the help of Bolwig's drawing apparatus. I am indebted to Statens Plantepatologiske Forsøg in Denmark for being allowed to carry out my studies there and to the chief of the zoological department of the laboratory, Dr. P. Bovien.

THE FEMALE REPRODUCTIVE ORGANS (fig. 1).

The two ovaries consist of two groups of *ovarioles*. The ovarioles unite each side by their anterior end to a *suspensory ligament* by which they are suspended. Each ovariole consists of three parts : a *terminal filament* (t.f.), an *egg tube* and a very short *supporting stalk* or *pedicel*. The principal part is the egg tube, which in its front part contains the *germ cells* (g.c.), the *germarium* (germ.), and behind these the derivatives of the germ cells: the *follicles* (fol.). The terminal filament continues from the anterior end of the egg tube and is a part of the suspensory apparatus of the ovary; the pedicel is the short ovariole duct uniting the egg tube with the *lateral oviduct*.

The covering of the ovariole is a thin structureless membrane, known as the *tunica propria* (t. pr.) which stretches over the terminal filament, the egg tube and the pedicel. No epithelial sheath is seen outside the tunica. The germ cells form a mass of cells in the front part of the egg tube. These cells form the follicles. In the posterior end of the *germarium*, little groups of cells (r.c.) are seen to be surrounded by elongated, cigar-shaped cells. The elongated cells form the *follicle cells* (fol. c.). Their nuclei are elongated like the cells themselves and they are dark. The little group of rounded cells is the *oöcyte* (oö.) and its *nutritive cells* (n.c.). The nutritive cells seem to be of germ cell origin. The oöcyte and its nutritive cells are produced by division of a single cell, the *oögonium*. Farther down the egg tube, the follicle cells form a single layer of cubical cells with dark rounded nuclei. Their number increases gradually as the follicle glides down through the tube. The rounded cells and their nuclei increase in size, the nuclei getting paler. In the posterior end of the tubuli, one of the rounded cells increases enormously and its plasma gets white and filled with yolk. Only a tiny bit of clear plasma surrounds the nucleus that remains in the anterior end of the egg. This cell is the *oöcyte* (oö), later the egg. When the oöcyte begins to increase in size, the follicle cells in the anterior end of the follicle flatten and soon after they die. The follicular cells surrounding the oöcyte stretch and form a columnar epithel. Later on they flatten too and die. The posterior end of the egg tubes appears to contain a little group of cells that forms a *plug*. The nutritive cells degenerate and form a *shield* (sh.) that covers the front part of the egg. When the egg is fully formed, the epithelium of the chamber begins a secretory activity producing a substance which is discharged upon the egg and hardens to form the egg shell. This shell is the chorion (chor.). On its outer surface, the

chorion retains the marks of the cells that produced it, in the form of honey-comb patterns of fine ridges reproducing the outlines of the cells of the folli-cular wall. The follicle cells cover the whole surface of the egg, with the exception of the front part which is covered by the degenerated nutritive cells. The pedicel is extremely short. A pair of lateral oviducts lead behind from the ovaries. They unite in an *oviductus communis* (od. c.). The posterior opening of the oviduct is the female gonopore. On the ventral side of the ovi-ductus communis a little, double-walled, bottle-shaped *spermatheca* (sperm. th.)
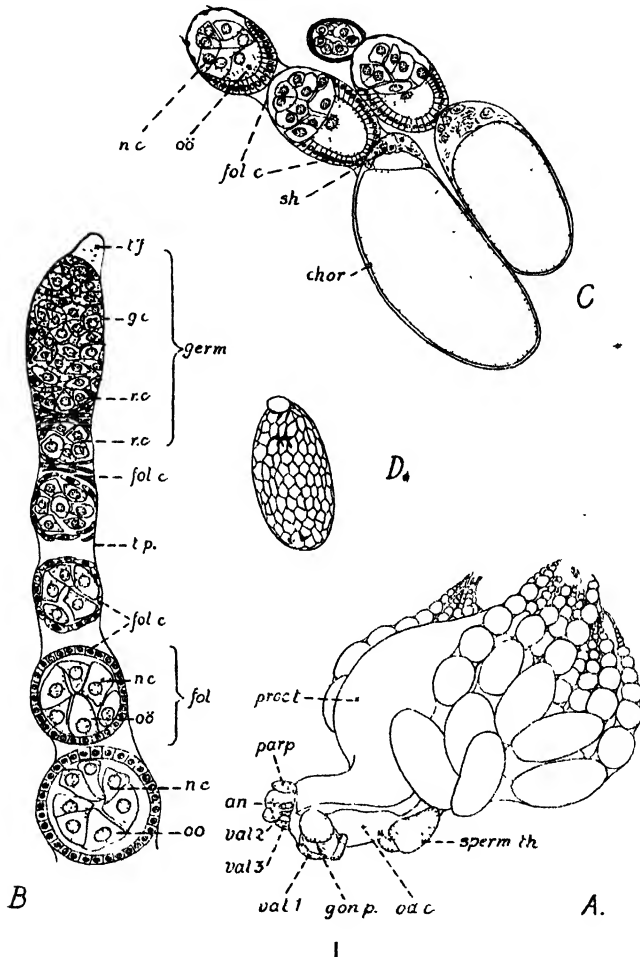
Fig. 1.— *S. unicornis* Czerny, ♀ reproductive organs. *A*, ovary; *B*, ovariole, upper part; *C*, ovariole, lower part; *D*, egg.

is seen. The spermatheca is darkly pigmented. The wall of the lateral oviducts, as well as the wall of the oviductus communis, is provided with an outer layer of circular muscle fibres and an inner layer of longitudinal muscle fibres. The gonopore (figs. 1 and 2, gon. p.) is situated between two little oval plates (val. 1) apparently behind the seventh sternite—but in reality

behind the eighth segment—however, the whole eighth segment, and the segments following as well, are rudimentary. The eighth and ninth segments are seen only as two fine ridges surrounding the rear end of the abdomen; one in front and the other behind the gonopore. In connection with the second ridge are to be seen three little, weakly chitinised, ventral lobes; two lateral (val. 3) and one median (val. 2). Probably the two lateral lobes (val. 1) of the gonopore are homologous with the first valvulae of the ovipositor of other insects. Similarly, the median lobe of the ninth segment (val. 2) is probably homologous with the second valvulae and the lateral one (val. 3) with the third valvulae of the ovipositor of other insects. Behind the three little lobes, and between a pair of oval paraprocts (parp.), the anus (an.) is to be seen.
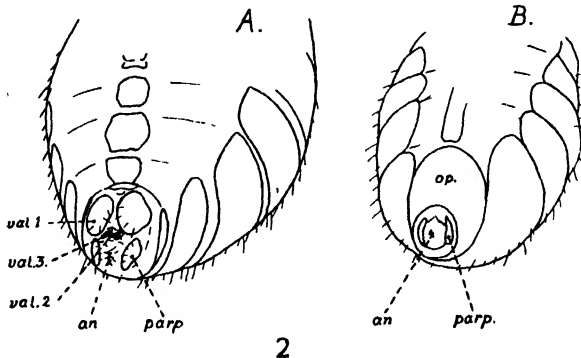
FIG. 2.—*S. unicornis* Czerny. Underside of end of abdomen. *A*, ♀; *B*, ♂.

THE REPRODUCTIVE ORGANS OF THE MALE.

The outer genitalia (figs. 3 and 4) of the male are minute. They are covered by a little strongly chitinised oval plate (figs. 2 and 3, op.). The anus is situated near the rear edge of the plate (fig. 2). A pair of little oval *paraprocts* (parp.) cover the anal orifice (an.). The *aedeagus* (aed.) is withdrawn into the cavity beneath the oval plate when not in use. It is a soft organ pointing forwards, the base of it being surrounded by two lateral bandlike sclerites (2) and a little ventral, V-formed sclerite (2). The opening of the V-formed sclerite points posteriorly. In the rear wall of the cavity, above the aedeagus, a little shield-formed sclerite (3) is seen. From the top of the shield a thin-forked arm follows the roof of the cavity. Laterally of the aedeagus a pair of oblong quadrangular inner forceps (i.f.) are to be seen. Their angles are drawn out in sharp points. They are about twice as long as they are high. Their upper angle at the rear end articulates to a sharp point on the edge of the oval plate. A very thin, chitinous arch (4) connects the upper angle of the front part of the two forceps. From the middle of the arch a very fine arm pointing anteriorly follows the roof of the cavity (5) and because of the folded roof of the cavity, it is bent like the letter S.

When coitus takes place, the aedeagus is pushed out of the cavity. During this action, the shield-formed plate is drawn downwards and forwards and rests in the dorsal wall of the aedeagus. The forceps turn round their articulation to the oval plate until standing perpendicularly on their ends. The top of the arch is drawn backwards so that the arch takes a horizontal position.
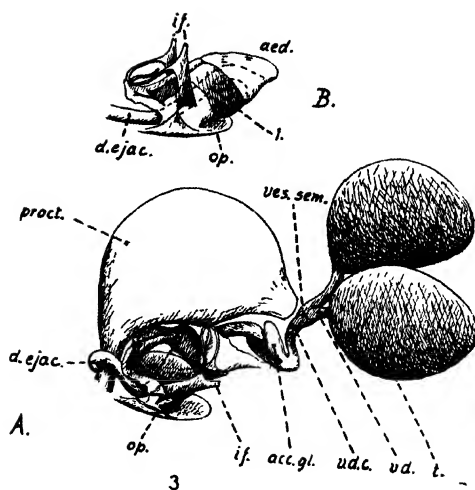
FIG. 3.—*S. unicornis* Czerny, ♂. *A*, reproductive system; *B*, sclerotised parts.
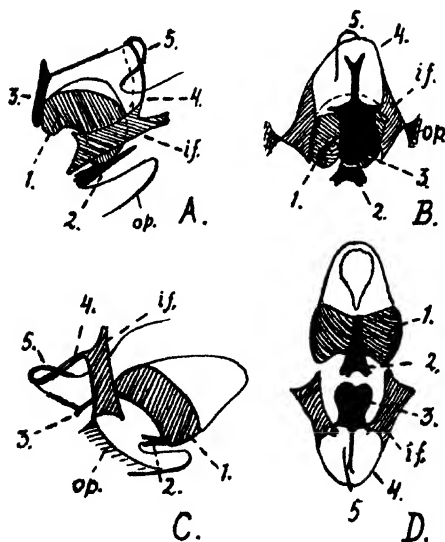
FIG. 4.—The sclerites of the hypopygium. *A*, seen from the right; *B*, seen in dorsal aspect; *C*, seen from the right, and *D*, seen in ventral aspect. *A* and *B* in resting position.

The *testes* (figs. 3, t. and 5) are a pair of orange-coloured, ovoid bodies situated on each side of the intestine in the abdomen. Their rear end is broadest. A slender tube goes out from the caudo-median end of each of the testes. The tubes are the *vasa deferentia* (v.d.). The two vasa deferentia unite into an unpaired *ductus ejaculatorius* (d. ejac.). A pair of *sac-like glands* (acc. gl.) open into the front part of the ductus ejaculatorius. The ductus ejaculatorius opens with its rear end on the terminal end of the copulatory organ : the *aedeagus* (aed.).
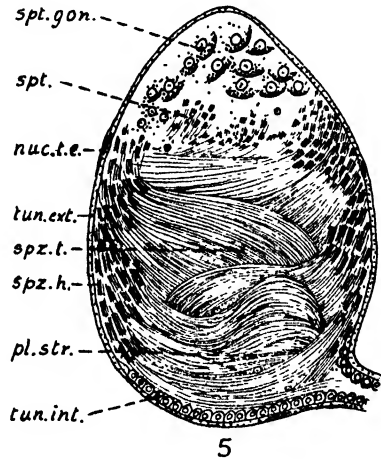
FIG. 5.—*S. unicornis* Czerny. Testis.

The outer surface of the testes is covered by a thin epithelial layer. This layer is the *tunica externa* (tun. ext.). It consists of flat, strongly pigmented cells, the nuclei (nuc. t.e.) of which are flattened. In the rear end of the testes another epithelial, *tunica interna* (tun. int.), layer is seen underneath the tunica externa. It consists of large cubical cells with large clear nuclei. In the front part the testes contain groups of cells. These cells are the *spermatogonia* (spt. gon.). Their nuclei are large and clear and their plasma is filled with a substance which stains strongly in haematoxylin. They seem to have lost their ability to form new *spermatocytes*. It must be supposed that they have a function as nurse cells for the *spermatids* and the *spermatozoa*. No *apical cell* is seen. Most of the space of the lumen of the testes is filled with *spermatozoa* (spz. h., spz. t.) and *spermatids* (spt.). They lie in bunches corresponding to the groups of spermatocysts in an earlier stage. These bunches of spermatozoa and spermatids are surrounded by *strands of plasma* (pl. str.) belonging to cells supposed to be derivates of spermatocyst cells (*Friele*, 1930). The spermatozoa have each a long slender head (spz. h.) and a tail (spz. t.) that, so far as I can see, is longer than the whole testes. The pigmented tunica externa, as well as the tunica interna, continue in the *vasa deferentia* (v.d.) fuse, and widen to a small *vesicula seminalis* (ves. sem.). From the vesicula seminalis a short, slender, pigmented tube continues posteriorly. This tube must be of the same origin as the vasa deferentia and the vesicula seminalis, and therefore I call it the " *vas deferens communis* " (v.d.c.). *Keuchenius* (1913) has described a similar unpaired vas deferens in SYRPHIDAE. Backwards the vas deferens communis continues in a long *ductus ejaculatorius*

(d. ejac.). The wall of the ductus ejaculatorius is much thicker than that of the vas deferens. On its outer surface it is covered by a very thin epithelial layer, the nuclei of which are very small and dark. The inner surface is covered by an epithelial layer of rather large cells. Between these two epithelial layers is seen a thick layer of circular muscle fibres.

Two little *sac-formed glands* (acc. gl.) open into the anterior end of the ductus ejaculatorius. Their walls consist of an outer very thin epithelial layer and an inner epithelial layer of large, low cells.

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AN ARTIFICIALLY PRODUCED MULTIPLE MIXED COLONY OF ANTS (HYM.)

By B. D. W. MORLEY, F.Z.S., F.R.E.S.

IN an earlier note (1939, *Ent. Rec.* **51** : 60) I recorded certain observations on a mixed colony of *Acanthomyops* (*Dendrolasius*) *fuliginosus* (Latr.) and *Acanthomyops* (*Chthonolasius*) *mixtus* (Nyl.) and also referred to an experimental introduction of some ♀♀ of the common black ant (*Acanthomyops* (*Donisthorpea*) *niger* (L.)) into the same nest. In that case some *niger* ♀♀ were introduced into a jar, in which some *fuliginosus* ♀♀ had previously been placed and later taken out, and left there for half an hour. The *niger* were then introduced into the mixed *fuliginosus–mixtus* colony. The object being to endeavour to pass on something of the extremely strong odour of the *fuliginosus* to the *niger* ♀♀ and thus facilitate the formation of an artificial mixed colony. This experiment was hardly a success; the *niger* habit of " saluting " (Donisthorpe, 1927, *Brit. Ants* : 208) seems to annoy the other ants concerned, though Donisthorpe (1927, *Brit. Ants* : 225) records a mixed *fuliginosus–umbratus–niger* colony which he produced in one of his observation nests.

It seemed to me that ♀♀ of several species might well be induced to live together peaceably if the species concerned were so chosen that their nest odours would not be entirely strange one to another and if this differentiation of nest odours was made less noticeable by a background of strong *fuliginosus* odour. Now *Formica fusca* L. and *Formica rufa* L. are not strangers, neither is *rufa* and *Leptothorax acervorum* (Fab.), nor *rufa* and *fuliginosus*. Thus ♀♀ of these four species might well live peaceably together.

I therefore introduced some *fuliginosus* into an observation nest with some *Leptothorax acervorum*, followed by a few *rufa* ♀♀ and next day some *fusca* ♀♀. The *fuliginosus* outnumbered the total number of all the other three species. These four species, after being a bit quarrelsome at first, soon settled down perfectly happily.

I then formed another similar mixed colony containing, as did the other one, a base of *fuliginosus*, but having *Acanthomyops* (*Chthonolasius*) *mixtus* (Nyl.), *Myrmica ruginodis* Nyl., and *M. laevinodis* Nyl., instead of *rufa*, *fusca* and *acervorum*. Once again it should be noted that the species concerned were chosen so that they would not be entirely strange to one another since they may meet in their natural habitat, and even intermingle. This colony also settled down peaceably. These two colonies were kept separate for a fortnight, and then put into one nest. Rather contrary to my expectations, but in accordance with my hopes, they mixed and settled down all right. Here then was a nest containing eight different species living together happily, though normally there would have been a battle royal; this result being achieved by means, apparently, of the *fuliginosus* with their strong nest odour, and careful mixing. Later some ♀♀ of the rather cowardly *Acanthomyops* (*Chthonolasius*) *flavus* (Fab.) were also put in, and settled down all right.

It is worthy of mention that only a few *rufa* ♀♀ can be placed in a plaster observation nest, as on hot days they tend to get excited and squirt acid, which, if there are many *rufa*, drops off the glass cover, killing both them and the other ants in the nest.

Mixed colonies were obtained artificially by Miss Fielde by means of (*a*) mixing the species in the pupal stage, and letting them hatch out as a mixed colony, and (*b*) by amputating the antennae of the ants concerned, as was pointed out by Donisthorpe (1940, *Proc. R. ent. Soc. Lond.* (C) **5** : 23) when I exhibited the colony to the Royal Entomological Society, but I believe that this is the first time that success has been achieved with adult, and uninjured, ants.

BOOK NOTICE.

Symposium on Fifty years of Entomological Progress.　*J. econ. Ent.* **33** : 8–65. 1940.

This symposium consists of 5 papers by C. L. Marlatt, L. Caesar, C. L. Metcalf, E. O. Essig, and S. A. Rohwer, each of whom writes of the progress made in one of the 5 decades from 1889 to 1939. The papers were read at a joint session of the American Association of Economic Entomologists and the Entomological Society of America, and it is natural that the main concern of the authors is the development of Entomology in the American continent. The American Association of Economic Entomologists was formed at Toronto in 1889 and its official publication is the *Journal of Economic Entomology*, of which 33 volumes have been published.

BOOK NOTICE.

The Problems of Insect Study. By P. KNIGHT. 2nd Edition. 4to. Ann Arbor (Edwards Bros.), 1939. pp. vii + 132, 22 pls., 31 figs. Price $2.50.

This book is lithoprinted in double columns and comprises 6 chapters : Chapter 1, The Insect problem; 2, man surveys the damage; 3, man counts the gains; 4, man appraises a competitor; 5, man classifies the Hexapods; 6, tentative solutions. Two appendices deal with the literature of Entomology and the common and scientific names of insects.

" The selection of the subject matter . . . has developed primarily out of questions of students and the introductory course in Entomology at the University of Maryland during the past 15 years."

" The final outcome was a course dealing with the science and problems of Entomology rather than a course about specific insects . . ."

The result is this book which gives a great deal of information of a popular interest which is not easily found elsewhere.

AN OUTLINE OF THE HABITS OF THE WATER-BEETLE, *NOTERUS CAPRICORNIS* HERBST (COLEOPT.)

By Frank BALFOUR-BROWNE, M.A., F.R.S.E., F.L.S., F.Z.S., F.R.E.S., and John BALFOUR-BROWNE, M.A., F.Z.S., F.R.E.S.

THIS is a joint paper because the honours as to the discoveries connected with the habits of the beetle are divided. The junior author first discovered the larva and how to obtain it in quantity, while the senior author discovered the pupa. It is now possible to outline the life-cycle of this species although, so far, all the details have not been directly observed.

Oviposition apparently takes place during the summer. This is deduced from the fact that, in various places observed, the imago is in abundance in the spring and becomes scarce about June, from which we conclude that the ovipositing females and their males are dying out about that time. The imagines are abundant again by the beginning of August, many specimens being soft, indicating the emergence of the next generation, but at that time small and large larvae and pupae are also obtainable, so that the breeding period presumably extends throughout the summer and early autumn.

The imagines, kept in an aquarium, spend a large part of their time burrowing in the soil and as the larvae live among the roots of water-plants in twelve to eighteen or more inches of water, it seems reasonable to assume that the eggs are laid where the larvae are found. From the nature of the ovipositor, it seems probable that the eggs are laid on, not in, the roots or are deposited on or in the mud, the larvae themselves in the latter case burrowing to their food. From watching the larvae, we have seen the rapidity with which they move through the soil at the bottom of the observation dishes, a quality which makes it difficult to discover them on the collecting sheet. The larvae are a pale yellow in colour and are found by pulling up plants of *Iris, Alisma plantago, Sparganium ramosum*, etc., amongst the roots of which they are common. Occasionally, an odd specimen floats to the surface as the plant is pulled up and this was how our first example was found. The insect was caught in the surface film and the net happened to catch it before it could release itself. But this searching of the water surface after pulling up the plant provides a poor harvest and the method the junior author quickly devised was to pull up the plant and immediately to get the net underneath it and then to wash the root thoroughly within the net. After considerable washing, the contents of the net were emptied on to the collecting sheet so spread as to leave a slight dip in the middle and some water was added, if necessary, so as to make a shallow muddy pool. This pool was then stirred up with the fingers and the larvae floated to the surface, where they were caught in the surface film and collected. Even so, perhaps only a single larva appeared but by repeating the stirring at intervals quite a number of specimens were taken from a single root. The senior author must confess that he was much less successful at this process, so that the personal element comes into play here as in all collecting. Once the method of finding the larvae had been discovered, it was easy to find them almost anywhere we searched for them.

A number of specimens was brought home and kept alive in flat glass dishes in which a small amount of soil had been placed and they at once exhibited the method of renewing their air-supply described by Wesenberg-Lund (1912), bringing the apex of the abdomen to the surface like any Colymbetine or Dytiscine larva. But it is obvious that larvae living in the mud in a foot or more of water cannot return to the surface at intervals in order to renew their air-supply, so that they must have some other method in deep water. It was noticed that the larvae in the flat dishes frequently placed the apex of the abdomen against pieces of root placed in the dish, but the attempts at piercing seemed very feeble.[1]

That the larva of *Noterus* does thus obtain its air-supply was suggested by G. W. Müller (1922) and it seems probable from the form of the apex of the abdomen. On the other hand, there is the possibility that the larva can obtain its air from the water, as do those of the Hydroporines, and in this connection it is interesting to note that the junior author has found that if these Hydroporines are kept in shallow water, they use the atmospheric air by bringing the apex of the abdomen to the surface. We mention this merely as a possibility although, from the habits in connection with pupation, it is obvious that the larva taps the plant root when it constructs its cocoon on the root, and therefore it almost certainly does the same during its feeding period. The cocoon is full of air so that when a plant upon the roots of which cocoons are attached is pulled up and vigorously shaken the cocoons float to the surface. I have seen these cocoons times innumerable but have always passed them over as seeds and it was only because we had found the habits of the larva that I opened some of them and discovered what they contained. There can be little doubt but that many entomologists have seen these cocoons and, doubtless, they have been seen by botanists and passed over as unimportant.

To those who know the life-history of the Chrysomelid beetles of the genus *Donacia* the similarity between it and that of *Noterus* will at once occur. MacGillivray described the life-history of these beetles in 1903. The larvae live in the mud on the roots of water-plants and possess two " caudal setae " which pierce the root tissues and, having the spiracular opening at the base, the air in the plant reaches the tracheal system of the larva. The full-grown larva forms an oval blunt-ended cocoon, which is at first transparent and is produced from a secretion from the larva. This cocoon is attached along one side to the root and the larva bites one or more holes in the root tissue to make contact with the air spaces of the plant.

MacGillivray stated (p. 312) that " if the place from which a cocoon has been removed is examined, there are found two slits near one end " in addition to the bitten hole, and points out that these slits are made by the caudal setae. In the two British species I have investigated, the slits are quite easily recognised beneath one end of the cocoon, but as *Noterus* builds its cocoon with its end on the root and bites a hole, like *Donacia*, for the air-supply, this hole occupies the whole surface of contact and the small puncture which the insertion of the apex of the abdomen would make is not recognisable.

MacGillivray did not explain how the cocoon becomes filled with air, merely stating that the larva entirely surrounds itself while spinning the cocoon " by

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[1] The larvae of *Donacia*, which also obtain their air from the roots of water-plants, were stated by Schmidt-Schwedt to insert their caudal spines into the tissue of the root when kept in the dark but to withdraw them immediately when brought into the light. (From MacGillivray, 1903 : 307.)

a quantity of air sufficient to fill the vacant space in the cocoon " (p. 313). The only possible explanation appears to be that the lacerated root tissues give off air, which is caught in the cocoon as it is being constructed and is sealed within it when the larva closes the distal end. We have to thank Professor F. T. Brooks for confirming this view of the action of the root. Once the cocoon is filled with air, exchange of gases will take place between it and the root as the larva or pupa exhausts the oxygen. It is to be noted that the cocoons of *Noterus*, opened while the larva is still within, are already filled with air and they reveal the larva with the apex of the abdomen at the root end, the larva lying curved almost double. The pupa invariably has the larval skin lying in a strong curve on its ventral side (pl. 1, fig. 6), its own abdomen being towards the root. The pupa, however, has no spine or piercing apparatus and is, in this, similar to that of *Donacia*.

It is interesting that two groups of beetles so widely separated as the Noterines and the Donacias should have developed such similar habits in the larval and pupal stages. There seems to be no doubt but that the *Donacia* larva is entirely vegetarian, and Wesenberg-Lund (p. 56) assumed from the form of the mandibles that the *Noterus* larva is the same. In our observations on the specimens in our dishes, they occasionally worked their mandibles upon the surface of the roots without, however, appearing to get anything off. They readily attacked dead *Chironomus* larvae and also dead individuals of their own kind but after an apparently ravenous attack lasting a very short time, the prey was left and not again attacked. As the larvae failed to live more than a few days in our dishes, we have not so far discovered their normal food, although it is possible to make deductions from a comparison of the mandible with that of *Donacia* (see p. 109).

The Larva (pl. 1, figs. 1 and 2).

A description of the larva may be useful as there has not previously been one in English and the accounts given by Meinert (1901) and by Wesenberg-Lund (1912) are not entirely accurate. Müller's (1922) description is somewhat vague and the one figure he gives of the apical abdominal segment is very sketchy. The colour, as already mentioned, is pale yellow, the underside of the abdomen white. The full-grown larva is about 9 mm. long and is narrow and resembles an Elaterid larva in general appearance (pl. 1, figs. 1 and 2). As Müller stated that the larvae he found were 6 mm. long (" apparently full grown but rather retracted "), it is possible that he had specimens of *N. clavicornis* as he suggested.

The head and thoracic segments are completely encircled with strong chitin, but all the abdominal segments have the ventral surface soft. Each abdominal segment is capable of being telescoped into the one in front of it and the eighth segment can be almost completely withdrawn into the seventh (see fig. 1, B).

There are eight pairs of abdominal spiracles in the third stage larva, one to seven being easily seen as small circular pits in the chitin at the sides of each segment, rather nearer the front than the back of the segment. The eighth pair lie side by side at the extreme apex of the segment, immediately beneath the chitinous point. These two spiracles communicate each with a " vestibule " in the segment into which the lateral tracheal trunk of its own side enters (see fig. 1, B). These trunks are apparently similar to those of other insects but the taenidial threads, which give the characteristic transverse

markings seen from the side, are only faintly visible. There do not appear to be any thoracic spiracles, but the tracheal branches, leading to where the mesothoracic spiracles would be, can be seen through the chitin.
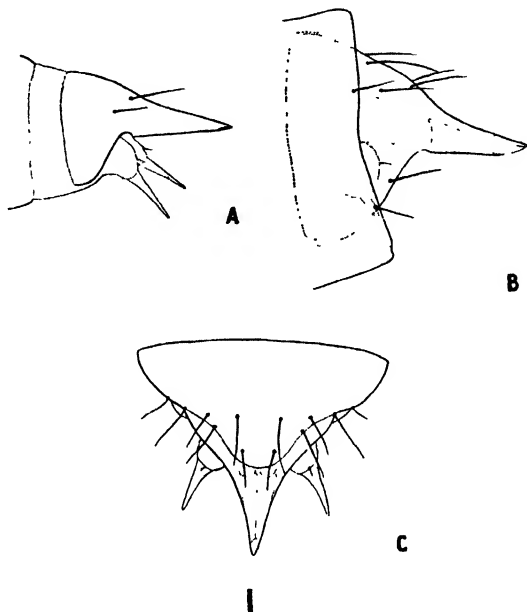
FIG. 1.—The last (eighth) abdominal segment of the larva of *Noterus capricornis* Herbst : (A) in a young larva, 3·5 mm. long; (B) in a full-grown larva, 9 mm. long, both seen from the side. In (A) the cerci are exserted and in (B), segment 8 is withdrawn into segment 7 and the cerci are packed away; (C) shows the dorsal view of the segment in a full-grown larva. Both (B) and (C) are from specimens boiled in potash and flattened on the slide.

The eighth abdominal segment (fig. 1) bears below the chitinous point a pair of small cerci, the bases of which are capable of being expanded or contracted so that the cerci may at one time project distinctly from the segment while at another they are only just visible. The anus lies below and between the bases of these cerci.

The Head Appendages.

The head bears the usual appendages. The antennae are 4-segmented and simple (fig. 3, A). The labrum (fig. 2, A) has a peculiar central part in which the epipharynx appears to break through to the upper surface. The maxillae (fig. 2, B) consist of a small basal cardo bearing a large stipes upon which are the 4-segmented palp and the subgalea carrying the galea. The basal segment of the palp appears to be part of the main structure of the maxilla but the palp is probably similar to that of other Dytiscids. Meinert (1901, pl. VI, fig. 155) figures a single hair on the penultimate segment of the palp but there appear to be single hairs on the outer side of each of the three basal segments

and also two hairs, side by side, in the membrane between the stipes and the basal segment of the palp, on the outer side.
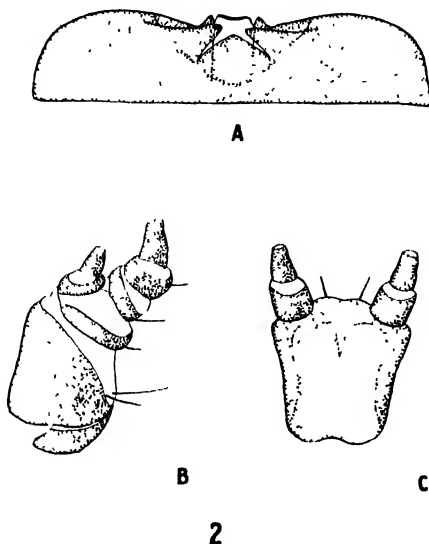
FIG. 2.—(A) labrum; (B) maxilla; (C) labium of larva of *Noterus capricornis* Herbst.

The labium (fig. 2, C) is simple and bears two 2-segmented palps and between them are two simple hairs. Meinert (pl. VI, fig. 156) figures each of these hairs as double but I could only agree with him by employing excessive magnification which, I believe, produced distortion.

The mandibles (fig. 3, B) are not quite as figured by Meinert (figs. 153, 154) or by Wesenberg-Lund (1912, pl. III, fig. 21b). From our figure it will be seen that the upper half is grooved down the inner face and toothed on both sides of the groove. This groove forms a pocket at its lower end, and about half-way down the inner face there projects a large pointed tooth, behind which is the pocket just referred to. Below this tooth is an edge armed with a few minute spines or teeth.

Snodgrass (1935 : 286) states that " with phytophagous species there is generally a well-marked differentiation in each mandible between a distal incisor lobe with cutting edge and a basal molar lobe provided with an irregular masticatory surface. In the predacious species, however, the grasping function of the jaws is more important than that of chewing, and in such species the mandibles are usually simple biting organs with strong incisor points which may be notched or toothed but in which effective molar surfaces are generally absent."

According to this definition, the mandibles should probably be regarded as of the predacious type but a comparison of them with those of *Donacia* (fig. 3, C) shows that there are similarities and that the *Noterus* mandible might be regarded as a modification of the phytophagous type. The apical point of the mandible of *Donacia* is slightly hollowed out on its ventral side, and the inner face, at the base, although not a true molar surface, bulges slightly. In

Noterus, the secondary tooth is much lower down and the molar process is absent. The general form of the mandible, however, suggests that it would still serve as an efficient organ for biting the root tissues, as it certainly does
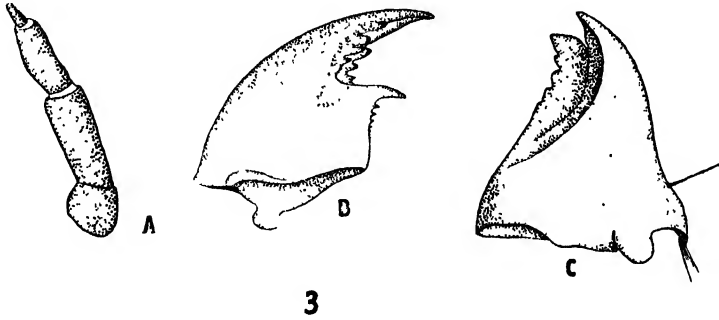
FIG. 3.—(A) antenna; (B) left mandible of the larva of *Noterus capricornis* Herbst; (C) ventral view of left mandible of *Donacia* sp. larva.
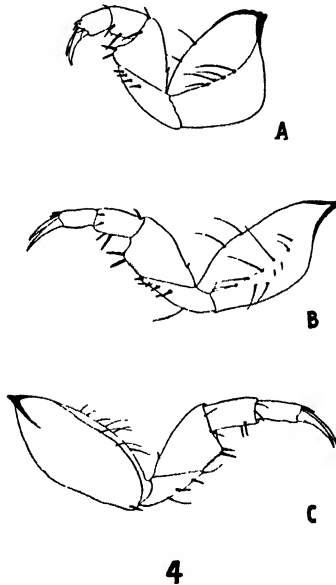
FIG. 4.—(A) right fore leg, anterior side; (B) right mid leg, anterior side; (C) right posterior leg, posterior side, of the larva of *Noterus capricornis* Herbst.

when arranging the air-supply for the cocoon, and that it would be suitable also for chewing animal organisms, as we observed it doing. Possibly, therefore, the larva flourishes on a mixed diet.

The Legs.

The descriptions of the legs given by the three authors referred to are incomplete and the figures given by Meinert and by Wesenberg-Lund are not quite accurate. The coxa is large and in the black chitinous structure at its base in each leg there are three minute circles arranged in a triangle which appear to be punctures going through the chitin. In some other larvae, *e.g.* some Colymbetines, similar spots occur but not, apparently, in groups of three.

The chaetotaxy of all legs is practically the same (fig. 4). The coxa has, on its upper or outer face, a flat area against which the closely united trochanter and femur lie when the leg is drawn up against the body. The posterior margin of this flat area carries two rather long fine hairs or spines, while the anterior margin, in the fore leg, carries four and in the mid and hind legs additional spines, about six along the margin and some more in the immediate neighbourhood.

The anterior face of the trochanter has always four short thick spines and the posterior face has two. The femur has a single small spur on its rounded dorsal side and on its ventral side at the distal end are a pair of strong spines. The tarsus consists of one segment and bears two freely movable claws, as in other Dytiscids. These claws are slightly different in length, the anterior being a little longer than the posterior. The figures show this difference and the whole of the chaetotaxy.

The Cocoon.

The full-grown larva constructs a cocoon of small pieces of vegetable material mixed with mud-particles on the roots of various kinds of plants growing in the water (pl. 1, figs. 3, 4 and 5). The cocoon is oval in shape, about 4·7 mm. long and is built end on to the root. It is strongly lined with a material, presumably produced by a larval secretion, and this lining covers the hole bitten in the root, so that all the inner surface of the cocoon is smooth.

We do not know how long the cocoon persists but it is probably not more than a few weeks and in this *Noterus* differs from *Donacia* in which the cocoon stage lasts " ten months or more " and " the pupa transforms to the beetle long before it is time for it to emerge." The imago of *Noterus* emerges in the same season in which the larva forms the cocoon by biting a more or less circular piece from the distal end.

The pupa (pl. 1, fig. 6) is white and of the usual coleopterous type.

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EXPLANATION OF PLATE 1.

FIG. 1. *Noterus capricornis* Herbst. The larva seen from the side. The photograph was taken from a specimen cleared with potash and mounted in balsam so that the spiracles on both sides of some of the abdominal segments are visible.

2. *Noterus capricornis* Herbst. Ventral view of the larva. The " soft " sterna of the abdominal segments are visible.

3. *Noterus capricornis* Herbst. Pupal cocoons on the roots of *Sparganium ramosum.* The circular exit hole made by the imago is visible in several of them.

4. Pupal cocoons of *N. capricornis.*

5. Pupal cocoons attached to a root.

6. Pupae of *N. capricornis* with the larval skin in its normal position.

BOOK NOTICE.

Sawflies of the Berkhamsted District, with a list of the Sawflies of Hertfordshire and Buckinghamshire, and a survey of the British Species (Hymenoptera Symphyta). By R. B. BENSON. *Trans. Herts nat. Hist. Soc.* **21 :** 177–231, 1940. Price 5s.

This work is the result of collecting carried out during the last 18 years by the author and the few published records of species taken in the area dealt with.

There is a very long introduction followed by the list of species to the number of 313. Four hundred and thirty-six species have been recorded from Britain. For each species the locality is given and some details of its frequency of occurrence and time of appearance.

BOOK NOTICE.

Insect Pests. By W. C. HARVEY and H. HILL. 8vo. London (Lewis), 1940. Price 10s. 6d. pp. ix + 292, 23 figs.

The authors of this book are a medical officer of health and a sanitary inspector to a local authority.

The book is in two parts : the first relating to insect pests and the second to principles and practice of disinfestation. There are two appendices giving samples of forms and propaganda leaflets suitable for use by a local authority.

There is a special chapter devoted to each of the following : the bedbug, the flea, and the louse and one chapter to the cockroach, cricket, silver fish, ant, itch mite, psocids, earwig, woodlice and the house fly.

The second part deals with building construction, fumigants, control and educational measures, legislation, and disinfestation of foodstuffs and ships.

Plate 1.
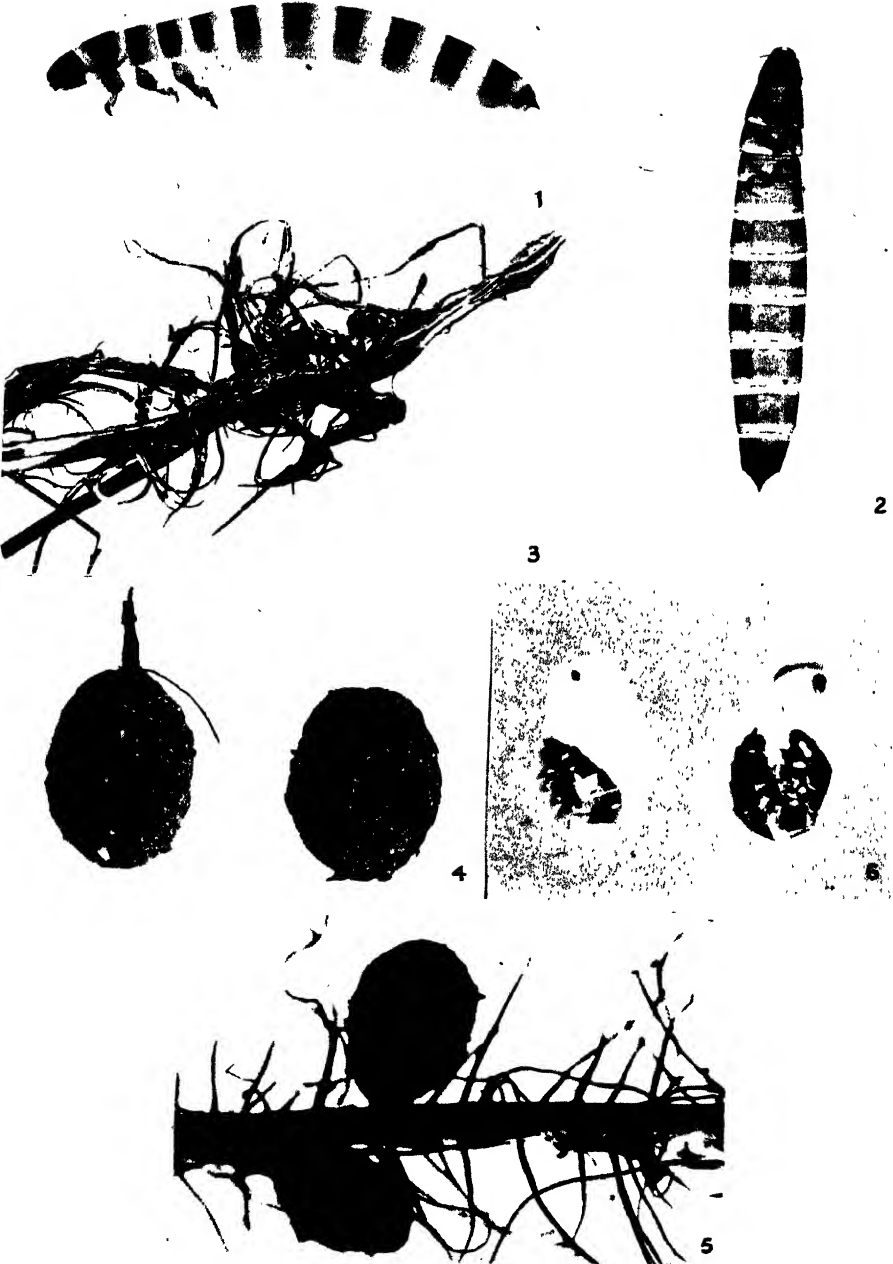
A FILTER-FEEDING MECHANISM IN A LARVA OF THE CHIRONO-MIDAE (DIPTERA : NEMATOCERA)

By E. T. BURTT, M.A., Ph.D.

(*Entomology Department, Zoological Laboratory, Cambridge.*)

Communicated by Dr. W. H. THORPE, F.R.E.S.

THIS paper deals with the method of feeding observed by me in the larva of the Chironomid *Glyptotendipes glaucus* (Mg.). I have also compared the behaviour of this Chironomid larva with what I could learn from the literature concerning comparable habits in the larvae of other species of Chironomids.

The larva of *G. glaucus* is found very commonly in the submerged leaf bases of the reed mace *Typha latifolia* L.; more particularly those which are dead and have already begun to decay. However, it is not restricted to this habitat, for I have found the larvae making their galleries in pieces of rotting submerged timber, and in the cavity of a drifting stem of *Phragmites*.

The structure of the larva itself calls for little comment. Its general appearance is shown in fig. 1, where it will be seen that it has the typical form of a Chironomid larva without any ventral so-called gill filaments, but with the usual anterior and posterior pairs of appendages armed with hooks. The arrangement of the mouth-parts and details of the antennae, mandibles and labium are shown in fig. 2. The larva attains a length of about 14 mm., and is bright red in colour owing to the haemoglobin present in the body fluid.

Some details of the pupa are given in fig. 3. The most characteristic features are the dorsal spatula-like projections on the 2nd, 3rd, 4th, 5th and 6th abdominal segments which coincide with dorsal depressions in the abdominal segments of the adult fly. The typical members of the genus *Glyptotendipes* show this character. Another character useful in separating different pupae is the form of the spines on the postero-lateral angle of the penultimate segment; the form of which is shown for *G. glaucus* in fig. 3, b and c.

The larval and pupal characters of this insect are very similar to those described by Gripekoven (1914) for the larvae and pupae of *Tendipes sparganii* Kieff., *T. ripicola* Kieff., *T. fossicola* Kieff., and *T. stagnicola* Kieff. The structure of the larva is also very similar to that described for *Tendipes gripekoveni* Kieff., although my larva is rather too small for *gripekoveni*. Both Edwards (1929) and Goetghebuer (1937) give *Glyptotendipes* (= *Tendipes*) *gripekoveni* as a distinct species judged from the adult, while the species which Edwards refers to as *Glyptotendipes glaucus* is designated *G. pallens* by Goetghebuer. The latter authority includes *ripicola*, *stagnicola* and *fossicola* under the one species *Glyptotendipes pallens* (Mg.).

THE FEEDING MECHANISM.

The larva eats out a tube in the leaf bases of *Typha*, making use of the elongated air cavities which fill the space between the two surfaces of the leaf. The larva starts by eating a round hole and crawling into one of the air spaces;

then it bites through the cross-walls which separate the air spaces until the gallery is long enough.   The inside of the tube is lined with a layer of silk spun from the salivary glands; at each end the tube opens by a distinct hole eaten through the cuticle of the leaf; and the gallery beyond this point is closed either by a silk wall or by a layer of silk applied to one of the cross-walls of the air spaces.   The arrangement of the tube is shown in fig. 1.
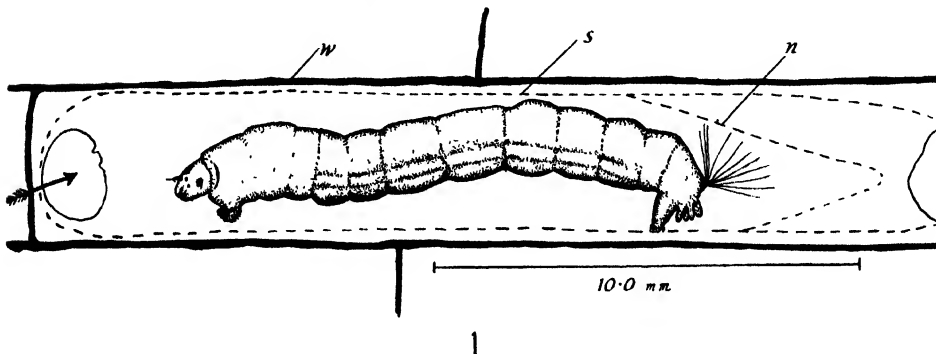
FIG. 1.—Larva of *Glyptotendipes glaucus* (Mg.) in its tube in a leaf of *Typha*.   The outer wall of the tube is imagined to be transparent.   Lettering—n, net; s, wall of tube; w, wall of air space.   The arrows show the direction of the current.

Within its tube the larva anchors itself by the fore and hind limbs to the lining of the wall and sends waves of movement down its body from head to tail : the plane of vibration of the body being the same as that of the paper in fig. 1.   This action has the effect of driving a stream of water through the tube; the particles carried in this current are caught; and form the chief food of the larva.   The mechanism of catching the suspended matter is as follows. The larva spins across its tube a web which is shaped exactly like a plankton net with its mouth lying towards the anterior end of the tube (see fig. 1).   The actual spinning of this net is difficult to follow because it is a very fine structure which is not distinctly visible until it has entangled a number of particles. The movements which accompany the weaving of the net are, however, very characteristic.   The larva presses its mouth against a point on the wall near the end of the tube and then moves sharply backwards (I interpret this as the action of fixing and drawing out the silk); then it moves slowly forwards, alternately contracting and expanding its fore legs (presumably pressing the silk into position).   These actions are repeated in several different planes (always starting from the same point of attachment) until the net is complete, when the larva turns round in its tube.   Owing to the narrowness of the latter, the larva has to bend quite double to get round and often spends some time cleaning the ventral side of its body during the process of turning.   Immediately the larva has reached its new position, it starts to send waves down its body from head to tail and soon the particles driven into the net render the latter clearly visible.   This is the position of the larva shown in fig. 1.   The pumping goes on for a few minutes and then the larva turns again in its tube, but now it seizes the open end of the net in its jaws and twists the net by rolling its body round its long axis, first in one direction and then in the other, devouring the net the whole time.   Once the mass of silk and its contained particles have been eaten, the larva starts to spin another net and the process is repeated.

The fine structure of the tube and net is best made out by staining a portion with borax carmine. A piece of the wall of the tube appears as a mass of fine wavy fibres less than $2\,\mu$ in thickness running in all directions. The net is very similar, only the fibres are not nearly as closely placed, and spaces varying from 5 to $40\,\mu$ are left between them.
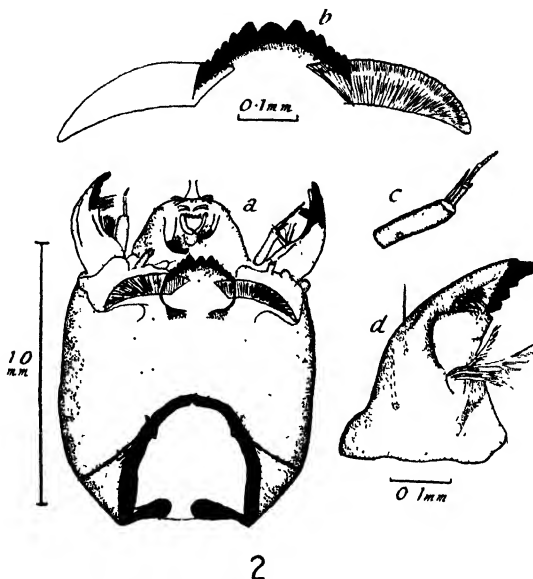
Fig. 2.—Larva of *Glyptotendipes glaucus* (Mg.). a. head in ventral view; b. labium; c. antenna; d. mandible.

It is interesting to watch the various ways in which the rhythm of spinning–pumping–eating may be modified. If one measures the number of beats made per minute while the larva is pumping and the duration of the period of pumping (or in other words, the interval between spinning and eating the net), one finds that the more rapid the strokes of the body, the shorter is the interval between spinning and eating the net. Below are some rates taken for the same larva at different times. The rate of beating was judged by taking the rate at intervals of one minute with a stop-watch, and then finding the average for the whole period. There was generally a slowing of the rate of beating towards the end of any one period. This may be due to the increased resistance of the net as it becomes clogged with particles.

Period of pumping	Rate of beating
45 minutes	44 per minute
$16\frac{3}{4}$,,	66 ,,
$14\frac{1}{2}$,,	68 ,,
12 ,,	81 ,,
$11\frac{1}{4}$,,	82 ,,
11 ,,	77 ,,
10 ,,	71 ,,
9 ,,	89 ,,
7 ,,	103 ,,
7 ,,	115 ,,
6 ,,	131 ,,

I have arranged the lengths of the periods of pumping in diminishing order; whence it will be seen that the rate of beating becomes, on the whole, more rapid, although there is no simple proportionality between the two. There are two rhythms in the feeding of this larva : there is the rapid beat of the body movements, and then superimposed on this is the slower rhythm of spinning, eating and turning round in the tube. Acceleration of one rhythm is accompanied by acceleration of the other.

Bright light and rise in temperature accelerate the rhythm. It is worth noting that transferring the larva from well-aerated water into water from which the air had been removed by evacuation caused no quickening of the pumping movements, although one cannot lay much stress on this observation in view of the low oxygen tensions that can be endured by haemoglobin-containing Chironomid larvae.
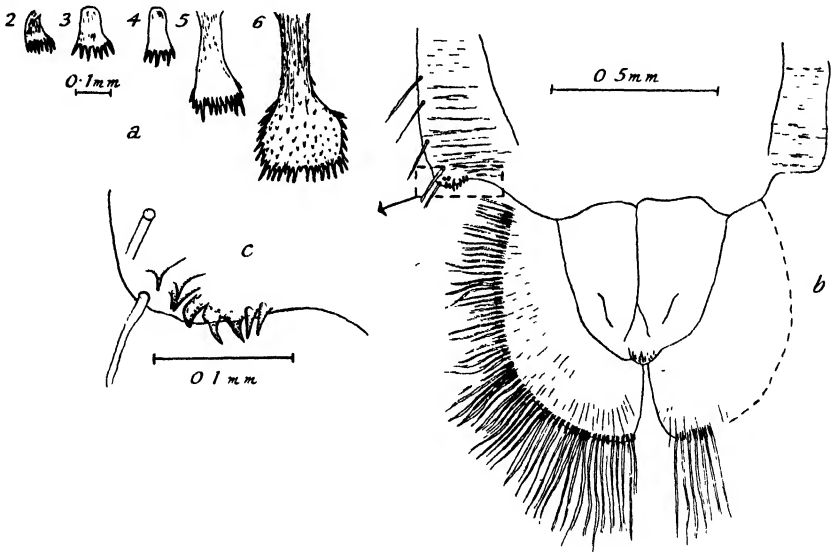
FIG. 3.—Pupa of *Glyptotendipes glaucus* (Mg.). a. appendages on the 2nd, 3rd, 4th, 5th and 6th abdominal segments; b. end of abdomen showing inset the posterior angle of the penultimate segment; c. spines on penultimate segment.

It is natural to wonder whether there is any relationship between the condition of the net and the length of the interval before the larva turns round and eats it : whether, in fact, the larva can be said in any sense to eat the net when it is full. The absence of simple proportionality between the period of pumping and the rate of beating suggests that this is unlikely. Unfortunately it is not feasible to remove the net while the larva is pumping to see what effect this would have on its subsequent behaviour, because any tugging at the net stimulates the bunch of hairs at the end of the body, and causes the larva to stop pumping and either crawl out of its tube, or turn round and move towards the disturbance with its mandibles open. However, one can determine whether the period of pumping preceding the eating of a heavily charged net is shorter

than that preceding the eating of a lightly charged one. It is very easy to add starch particles to the water which passes through the tube and thus add enormously to the amount of material in the net. Using a second larva the following figures were obtained :—

	Period of pumping		Rate of beating
With starch	5¼ minutes		104 per minute
	4¾	,,	96 ,,
No starch	6¾	,,	96 ,,
	5¼	,,	105 ,,

A slight quickening was noticed in this case, but in no sense was it equivalent to the enormously different state of the net with clear water and starch suspension.

A number of observations were made on another species of net-making larva regarding its reaction to the blocking up of the tube. The larva of *Pentapedilum tritum* (Walk.) (see below) was very convenient on account of the small size of its tube. The anterior opening of the tube was blocked with a piece of silk taken from the tube of another larva, and at once the pumping became slow and laboured. I suspect that the larva becomes aware of the blockage by the increased resistance to the pumping movements. What usually happens is that the larva reverses the beat for a few strokes and then, if the blockage continues, it ultimately crawls to the anterior opening, eats a way past the obstruction and lines the new passage with silk. If the posterior opening were plugged, the larva still behaved in the same way and pushed its head through the perfectly free anterior opening several times : finally it turned round and ate the net, and, making a few pumping movements in this position, it encountered the resistance and then its response resulted in the clearing of the tube. The last observation shows how much the behaviour is adjusted to deal with those events which are normally encountered, but not with novel ones.

NATURE OF THE FOOD.

An examination of the net of a larva shows that the objects entangled consist of readily recognisable planktonic objects such as diatoms, algal cells and clumps of bacteria. Added to this are masses of material without any readily visible structure, but which arise in all probability from the decay of the plants in which the tube of the larva is made. It will be clear from what has been said of the feeding mechanism, that the larva exercises no selection on the objects which pass into the net.

SIMILAR NET-MAKING IN OTHER CHIRONOMID LARVAE.

I have tried to find how widespread this catching mechanism is among Chironomid larvae, and whether it is found in all those species which live in the stems of aquatic plants.

So far as I know the first careful account of a Chironomid larva living in the tissues of aquatic plants is due to Willem (1908). Under the name of *Chironomus sparganii* Kieff. he described a larva which, from the form of its mouth-parts, and from the possession of the characteristic dorsal spatula-like structures on the abdominal segments of the pupa, must be in the genus *Glyptotendipes* and perhaps is *G. glaucus* itself. He described the gallery made by the larva and stated that the food consists of diatoms, algae, etc., which get entangled in

the silk walls of the tube and are scraped off by the larva. He does not describe the spinning and eating of the net. Gripekoven (1914) described over 30 species of Chironomid larvae which mine in aquatic plants, and among them some which have characters (*e.g.* the structures on the abdominal segments of the pupa) which place these larvae in the genus *Glyptotendipes*, but nowhere does he describe the peculiar feeding mechanism. He confirmed the account of Willem and suggested that the plankton is caught on the walls of the tube and that the bunch of hairs at the end of the body also acts as a trap.
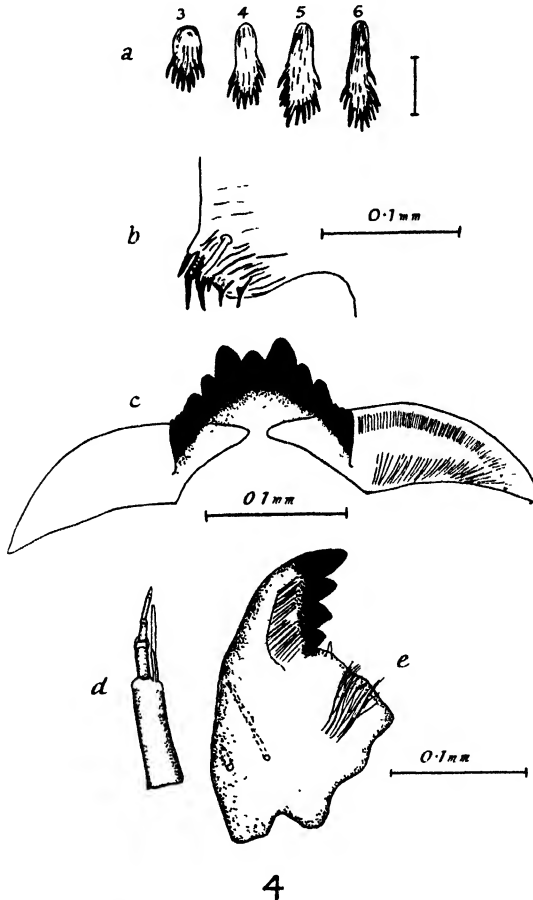
FIG. 4.—*Glyptotendipes imbecillis* (Walk.) pupal and larval characters. a. structures on 3rd, 4th, 5th and 6th abdominal segments of pupa; b. spines on penultimate segment; c. labium of larva; d. antenna of larva; e. mandible of larva.

One might suppose that the net was a peculiarity of *Glyptotendipes glaucus*, but this is not so. I have found virtually identical behaviour in the larvae of *Pentapedilum tritum* (Walk.) and *Glyptotendipes imbecillis* (Walk.). The habits of these larvae are so similar to *Glyptotendipes glaucus* as not to require detailed description. They live in very similar habitats but their tubes are smaller in

accordance with their size and the rate of their movements is more rapid under the same conditions. In both cases the larvae were reared and their species determined from the resulting adults. The general appearance of the larva of *G. imbecillis* is very similar to that of *G. glaucus* shown in fig. 1; but it is markedly smaller, not reaching more than 9 mm. in length, and the head seen in ventral view has a more elliptical shape. The colour of the body is bright pink. Details of the labium, mandible and antenna are shown in fig. 4, c, d and e. The pupa has the peculiar structures on the dorsal surfaces of certain abdominal segments which may be seen in *Glyptotendipes glaucus*, but in *G. imbecillis* the 2nd segment does not bear one and they are present on the 3rd to 6th segments inclusive. The spines borne by the postero-lateral angle of the penultimate segment are shown in fig. 4, b.
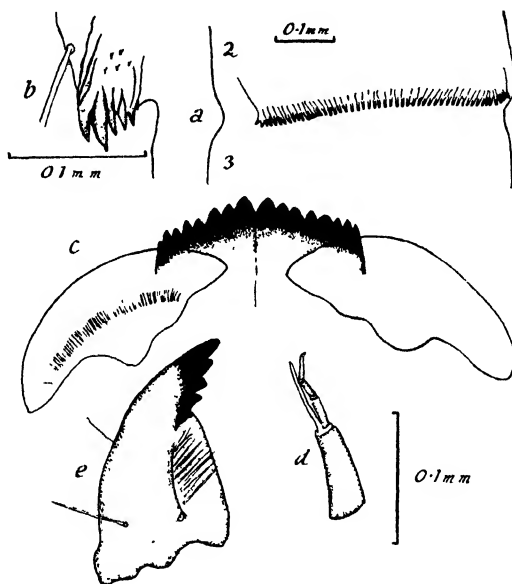
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Fig. 5.—*Pentapedilum tritum* (Walk.) pupal and larval characters. a. comb on 2nd abdominal segment of pupa; b. spines on penultimate segment of pupa; c. labium of larva; d. antenna of larva; e. mandible of larva.

There are two larvae in Gripekoven's account which closely resemble the above: viz. *Tendipes caulicola* Kieff. and *T. candidus* Kieff., and of these two *T. candidus* shows the more points of similarity to *G. imbecillis*. I note that, from the description of the adults, Edwards tentatively included *candidus* in *Glyptotendipes viridis* (Mcq.), which last is a species very similar to *G. imbecillis* Walk. and perhaps should not be separated from it. Goetghebuer included *candidus* in *Glyptotendipes severini* Goet., which again is very similar to *G. imbecillis*.

Some larval and pupal characters of *Pentapedilum tritum* (Walk.) are shown in fig. 5. The larva attains a length of about 7 mm. and is pale pink in colour.

The most noticeable larval character is the divided middle tooth of the labium. The pupa has very few characters which enable one to identify it easily. The spines on the angle of the penultimate segment are shown in fig. 5, b and a comb-like structure on the end of the second abdominal segment is drawn in fig. 5, a. Gripekoven referred to two species of *Pentapedilum*, of which one, namely *P. stratiotale*, is, judging from the characters of the pupa, very similar to *Pentapedilum tritum* : the structure of the larva is not described. Edwards (1929) tentatively included *P. stratiotale* Kieff. in *Pentapedilum tritum* Walk.

One may assume that the net-making habit is present in all the species of *Glyptotendipes*, and perhaps it is characteristic of all Chironomid larvae which make galleries in the tissues of water-plants. I have not yet succeeded in finding Chironomid larvae with similar behaviour among those which live in mud or among masses of algal filaments. In such cases the food is taken in directly from the substratum and although the body makes movements which drive water through the tube, the current so produced is not used to catch food, and presumably is essentially respiratory.

CASE-MAKING CHIRONOMID LARVAE.

Lauterborn (1905) described a number of oddly shaped cases made by Chironomid larvae recalling the cases of Caddis-fly larvae. Among them is one of a vase-like shape with arms spreading from the wider end. Lauterborn stated that these arms catch particles which drift past in the stream. Bause (1914) referred to these cases but doubted whether the arms are used to catch objects. Mundy (1909) gave some very minute observations on the behaviour of a case-making larva, but his work was printed privately and it escaped Bause's attention. Mundy described a larva under the name of *Chironomus pusio* Meig. which, from the morphology of its antennae, mandibles and labium, and from the shape of the case, agrees with the *Tanytarsus raptorius* Kieff. of Bause's account. Mundy described the building of the case in *Tanytarsus raptorius* and another larva in which the case is very similar but attached at the base by a stalk. Both these larvae live in rapidly flowing streams. Mud, cemented with silk, is gathered round the body to form the main part of the tube and then arms are made by sticking pellets of mud and silk one upon the other at points on the rim of the case. To make a net the larva runs up one of the arms, swings across to the next arm, carrying a thread of silk with it, and then moves across again, retreating as it does so until the space between the two arms is filled with a meshwork of threads. The net entangles particles from the moving water of the stream and from time to time the larva gathers up the region of the net lying between two arms and either eats it, or uses it for further building. This behaviour is reminiscent of that of the net-making Trichopterous larvae of the families HYDROPSYCHIDAE, PHILOPOTAMIDAE and POLYCENTROPIDAE, where a net is spun in front of the tube which entangles objects swept into it by the stream. There are, however, certain differences judging from the accounts of Wesenberg Lund (1911) and Noyes (1914). The net does to some extent entangle food in the form of diatoms but more typically it acts as a snare for larger organisms such as Ostracods, *Simulium* and Chironomid larvae; also the net is cleared of its contents by the larva going over it and is not periodically eaten and then respun.

Lauterborn (1905) also described several other peculiarly shaped cases which were made by Chironomid larvae living among the masses of vegetation in swamps, in particular one case-making larva which was figured by Réaumur

(1738). Bause (1914) referred to this larva as *Tanytarsus flexilis* and Edwards (1919) added further details of the eggs, early larval instars and form of the case. He called the species *Chironomus clavaticrus* Kieff. but later (1929) included it in *Lauterborniella marmoratus* (van der Wulp). The larva can move about in its case and protrude its head from either end : observations of its feeding habits would be interesting. The behaviour of *Glyptotendipes glaucus* Meig. and *Tanytarsus raptorius* suggest that there are probably other interesting methods of catching food among the larvae of the CHIRONOMIDAE.

I wish to thank Dr. W. H. Thorpe for his kind advice and criticism in the preparation of this paper; Dr. F. W. Edwards, F.R.S., for identifying material and Dr. A. Thienemann of Plön for assistance with the literature.

SUMMARY.

The larvae of *Glyptotendipes glaucus* (Mg.), *Glyptotendipes imbecillis* (Walk.), and *Pentapedilum tritum* (Walk.), make silk-lined tubes in the tissues of aquatic plants. The movements of the body of the larva cause a current of water to pass through the tube. The particles thus carried in are caught by a net which is periodically eaten with its entangled particles, and another one is spun in its place. The habit seems to be peculiar to those species living in water-plants. Attention is drawn to the peculiar cases made by certain Chironomid larvae which are referred to by various authors, and an account is quoted of a Chironomid larva, living in streams, which catches particles by spreading a net from the end of its tube.

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THE HEAD OF *SCATOPHILA UNICORNIS* CZERNY (DIPTERA)

By Niels Bolwig, M.Sc., F.R.E.S.

WHEN redescribing *Scatophila unicornis* Czerny (EPHYDRIDAE, Diptera) I found that many of the structures of the head were so easy to see that it seemed worth while to study them a little more closely. This was confirmed by discovering that relatively few investigations have been carried out on this subject. The study was carried out by simple dissection under a microscope, or by examination of the whole head under a binocular, or monocular, microscope. The head of a newly hatched fly is the best subject. All the diagrams were made by the help of Bolwig's drawing apparatus. I am indebted to Statens Plantepatologiske Forsøg for being allowed to carry out my studies there and to the chief of the Zoological department of the laboratory, Dr. P. Bovien.
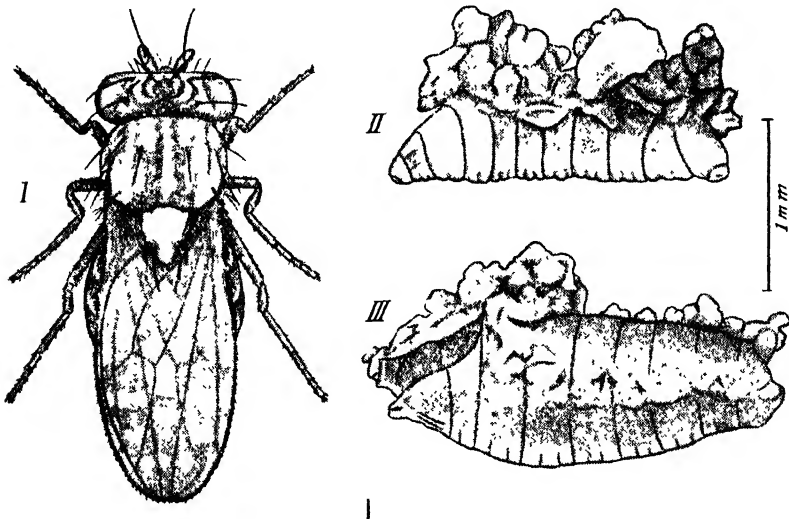

FIG. 1.—*S. unicornis*, I. Imago, II. Larva, III, Puparium.
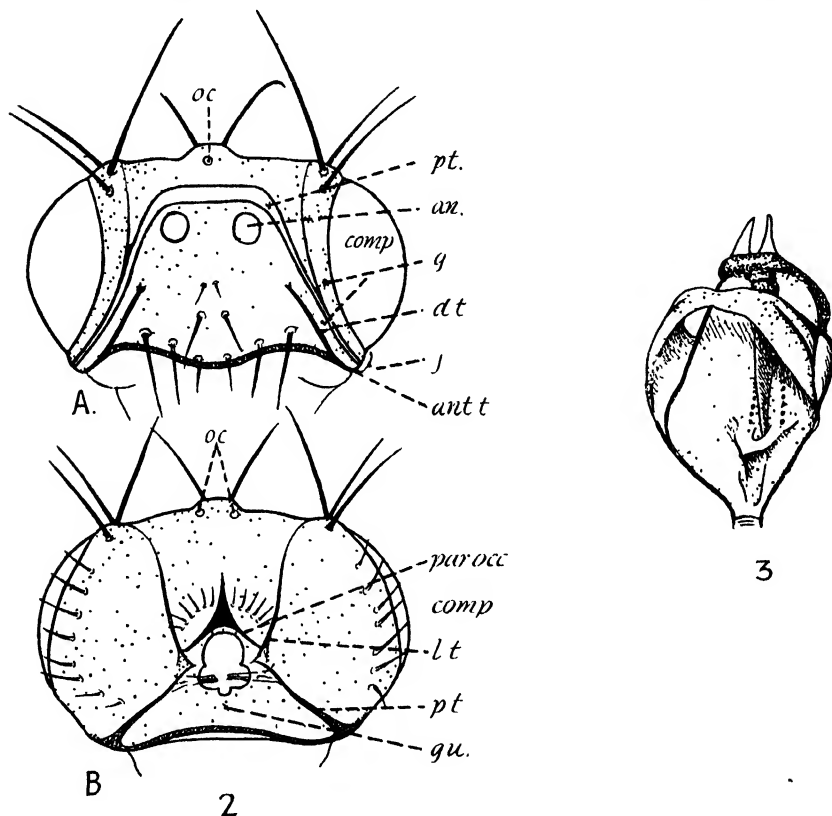
THE HEAD CAPSULE.

The hypothetical head capsule of a fly has on each side a pair of large compound eyes. An *occipital foramen* is situated on its posterior aspect; another, very large orifice, the *mouth opening*, is situated in its lower side.

From the occipital foramen extends a suture over the dorsal side of the head passing down over the anterior surface of the head where it forks. Each of the arms continues down towards the mouth opening. This suture is named the *epicranial suture.*

On each side of the upper branch of the epicranial suture, just above the place where it branches, the *antennae* are situated.

The area between the two arms of the epicranial suture is named the *frons* (Peterson) (= the *praefrons*, de Meijere, 1915). The part of the head above the arms of the suture is named the *vertex* (Peterson). The antennae are situated

FIGS. 2–3.—2. *S. unicornis*, head capsule; 3. *S. unicornis*, fulcrum.

in the vertex. Above the antennae is a suture formed like an "n". This suture is the *ptilinal* or *frontal suture.* From this place, the young fly can push out the *ptilinum* or *frontal sack*, by help of which the fly bursts the puparium when emerging. On the top of the head is seen a small plate on which three small *ocelli* are seen, the one in front of the others. The area of the vertex near the compound eyes is called the *temple.* Downwards between the eyes and the ptilinal suture, the vertex continues in the *genae* (Peterson). These again continue in the *jowls* (= *genae*, Peterson), the part of the head between the eyes and the mouth opening. The antennae are often situated in grooves. These grooves are the *antennal grooves.* They extend from the base of the antennae to the mouth opening.

" No sutures occur on the caudal aspect of the hypothetical head-capsule, except the epicranial suture. This absence of sutures makes it impossible to locate definitely the boundaries of the occiput and the postgenae " (Peterson, 1916 : 23). The area dorsal of an imaginary line drawn through the middle of the occipital foramen is called the *occiput* (Peterson, 1916 : 23). The area ventro-laterally of this line has been called the *postgenae* by Peterson. The area just beneath the occipital foramen is named the *gula* by most authors. Peterson supposed that this area is made by fusion of the median borders of the postgenae.

The head of most insects has an inner skeleton, the *tentorium*, formed by three pairs of invaginations. These invaginations are seen as impressions of the head capsule. The one pair of impressions is seen just below the antennae, in the arms of the epicranial suture. From this point a pair of slender arms extend downwards and backwards into the cavity of the head capsule. These arms are the *dorsal arms* of the tentorium. In their distal end they fuse with another pair of arms : the *anterior arms* of the tentorium. They extend backwards from another pair of impressions in the epicranial suture just above the mouth opening. In the middle of the head the anterior arms meet and fuse with the *posterior arms* that point forwards from a pair of impressions just below the occipital foramen.

The dorsal half of the occipital foramen is strengthened by a thickening of the lower edge of the occiput. This thickening is named the *paraocciput* by Peterson. It is provided on each side with an articulation to the *cervical sclerites*. Below the occipital foramen is another thickening, the *parapostgenial thickening* (Peterson). The posterior arms of the tentorium arise from this thickening.

The head capsule of *Scatophila unicornis* (fig. 2) is strongly pigmented. Its colour is dark brown. In most parts of the head the true colour cannot be seen because of fine structures in its surface that give it a whitish, powdery appearance. Some places appear more powdery than others which show certain definite ornaments.

The head capsule is broader than high. Its anterior aspect is convex. The back of the head is flattened. The mouth opening is very wide. The *genae* (g) and *jowls* (j) are very short. The *ptilinal suture* (pt. s.) stretches nearly all the way to the mouth opening. Just as in most Diptera, there is no *epicranial suture* present on the vertex. Below the antennae is seen a pair of small invaginations. From these invaginations a pair of chitinous thickenings extend (d.t.) downwards to the mouth opening. Here they join another thickening, following the mouth opening all the way round. From the occipital foramen another pair of thickenings (p.t.) extend downwards and fuse with the thickening that surrounds the mouth opening. The triangular plate between the occipital foramen, the mouth opening and the thickenings that extend from the occipital foramen to the mouth opening, is the *gula* (gu). Most authors agree that the above-mentioned thickenings are the tentorium laid up to the head capsule and fused with it. Meanwhile there is some disagreement in explaining the homology of the thickenings. Most authors are of opinion that those extending from the impression beneath the antennae to the mouth opening (d.t.) are homologous with the *dorsal arms* of the tentorium. The lateral thickenings (ant. t.) of the edge of the mouth opening are then supposed to be homologous with the *anterior arms* of the tentorium, while the thickenings stretching from the occipital foramen downwards (p.t.) to the mouth opening are supposed to be homologous with the *posterior arms* of the tentorium. Against this point of view is that of Frew (1923). He has found that the thickenings

of the anterior surface of the head of *Chlorops* extend, not from a point below the antennae, but from a point between the antennae from which the thickenings go upwards and outwards, round the base of the antennae, so that the antennae are placed between the thickenings instead of outside and above them. This means that if the antennae are considered to be the dorsal arms of the tentorium, marking the lower arms of the epicranial suture, it would be necessary to consider the area in which the antennae are situated as the frons. Such a position of the antennae is not known in insects. Therefore Frew concluded that the thickenings, extending from the antennae to the mouth opening, cannot be homologous to the dorsal arms of the tentorium. He tried to find the dorsal arms somewhere else. Peterson said in his description of *Tabanus* (1916 : 28) that " the invaginations of the lateral half of the head are joined together by the arms of the epicranial suture." Frew saw a similar connection in the thickening of the anterior margin of the mouth opening, which means that he considered the whole anterior surface of the head as the vertex.

I cannot say whether Frew is right or not, but the depression at the upper end of the thickenings below the antennae seems to prove that the ridges of *Scatophila* and at least the lower end of the ridges of *Chlorops* are homologous with the dorsal arms of the tentorium. Therefore, I think it right, until something more definite is known, to consider the thickenings below the antennae in *Scatophila* as homologous with the dorsal arms of the tentorium and the area between them to be the frons (Peterson).

The antennae are situated in the upper end of a pair of very low impressions. These impressions are the *antennal grooves*. In the males, the front is drawn out in a little " nose " just above the mouth opening (fig. 1).

Besides the tentorial thickenings of the rear head there is a thickening above the occipital foramen, this is the *paraocciput* (Peterson). Its middle is drawn out in a thickening that stretches upwards towards the ocelli. Laterally it joins a pair of thickenings (l. th.) which stretch towards the upper end of the compound eyes.

THE ANTENNAE.

The *antennae* are composed of three segments. They are inserted in the middle of the anterior aspect of the head capsule in the upper end of the antennal grooves. The first segment is formed like a little cone which is inserted into the head capsule with its top. The second is conical also, but a little compressed from side to side; its distal end is surrounded by an edge on which are situated a row of dark bristles pointing forwards. The third segment is nearly as long as the first two together and is strongly compressed from side to side. In side view it is almost ovoid and inserted into the second segment with its broadest end. Its surface is covered with little hairs. On its dorsal side, near its base, is inserted a long, bent, black, pubescent bristle pointing forwards. This bristle is the so-called *arista*. The arista is not a true bristle, but the rudiment of the distal end of the antennae. That it is so is proved by a little chitinous ring that separates the main part of the arista from the third segment of the antennae.

THE PROBOSCIS.

The proboscis consists of three parts, named respectively from above downwards : the *basiproboscis* or the *rostrum* (rost.); the *medioproboscis* or *haustellum* (haust.); and the *distiproboscis, oral disc* or *oral sucker* (or. d.). When at rest, the parts are flexed on each other, but the proboscis, because of its great size, can only be partly withdrawn within the head capsule. When fully extended,

it projects downwards, the three parts being nearly in a straight line. When extended, it forms a broad inverted cone. The extension is, according to Lowne (1890–92), brought about by distention of large air-sacks which are contained within it. The retraction and the varied movements of the proboscis are produced by muscular action. For the most part it is covered by a thin membranous wall, but this wall is in some places interrupted by thicker chitinous sclerites to which muscles are attached.

THE SKELETON.

The *rostrum* (rost.) is the basal part of the proboscis. Its wall is a thin flexible membrane that is attached proximally to the margin of the epistomal orifice in front of the head capsule. These margins are formed in front by the
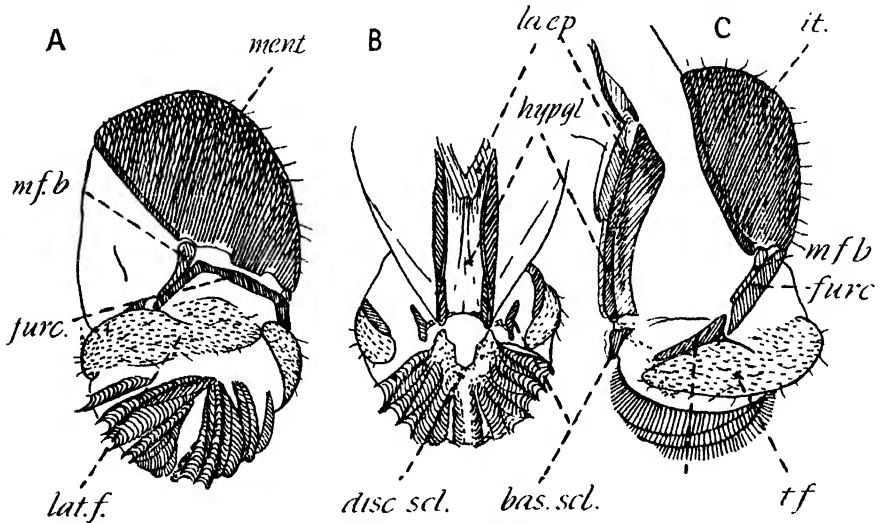

FIG. 4.—*S. unicornis*, the haustellum and the oral disc seen in A, nearly ventral aspect, B, from the dorsal side (the hypoglossa, hyp. gl., is pressed open by the covering glass) and C, from the left side.

facial plate, laterally by the *genae* and posteriorly by the *postgenae*. At its distal end, the wall of the rostrum is continued with that of the *haustellum* (haust.). In the anterior or dorsal surface of the rostrum is a dark horseshoe-shaped sclerite, the anterior arch of the internally-placed *fulcrum*. Lowne (1890–92) and Graham-Smith (1930) describe a little plate between the anterior arch of the fulcrum and the margin of the facial plate (the *epistome*) in the blow-fly. In *Scatophila unicornis* there is no such plate. Below the visible part of the fulcrum there lie on either side of the middle line the clavate *maxillary palps*. As in the blow-fly, no *palpigerous scale* is developed. The palpi articulate directly in the membranous skin of the rostrum. They are reddish-brown, pubescent and, near their end, carry two small dark hairs. In the blow-fly, a little *sesamoid sclerite* is seen at each side of the proboscis near its distal end to which are attached muscles. There are no such sclerites in *Scatophila unicornis*.

The most important structure of the rostrum is the *fulcrum* (fig. 3). The

fulcrum is in the form of a stirrup, the visible part being at the top of the bow. The rest of the fulcrum is situated inside the rostrum. The sides of the arch form the *lateral plates*. The sole of the stirrup is large and oval and has its longest axis extended in the same direction as the main axis of the rostrum. In its upper end, the sole bends forwards towards the facial plate. From the edge of the upper end of the sole a pair of small *cornua* project upwards and backwards towards the vertex. Another pair of cornua project downwards from the lower end of the fulcrum. The sole and the lateral plates of the stirrup are double-walled. The sole consists of an outer ventral plate (fig. 8), the *hypopharyngeal plate* (hyp. ph. pl.) and an inner *epipharyngeal plate* (ep. ph. pl.). The hypopharyngeal plate is firmly connected to the lateral plates, while the epipharyngeal plate is connected to the lateral plates by a thin sheet of chitin
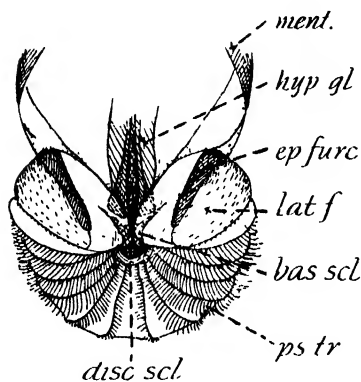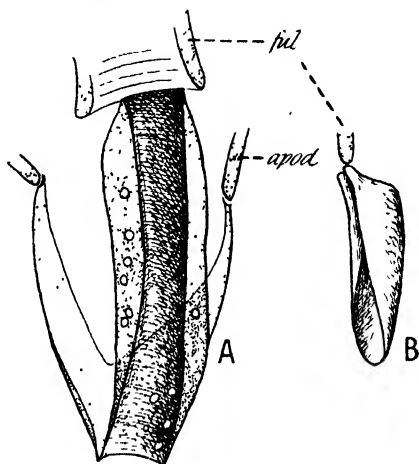
Figs. 5-6.—5. *S. unicornis*, the oral disc fully expanded; 6. *S. unicornis*, the labrum epipharynx and hypopharynx.

that passes from the edge of the lateral plates. The cornua are situated on the hypopharyngeal plate. The *pharynx* is situated in the cavity between the two walls of the fulcrum. The epipharyngeal plate is strengthened by a *median ridge* or *raphé*. Distally the raphé is interrupted and crossed by a *transverse ridge*. On either side of the median a row of fine pores is seen. In every little pore is placed a small seta. The setae turn towards the *oesophagus* and are flexible. Two slender rods stretch from the distal end of the rostrum lateral of the fulcrum. These rods are called the *apodemes* (apod.) and are **S**-shaped with a notched head.

The *haustellum* (haust.) or *medioproboscis* (figs. 4 and 5) is the centre part of the proboscis. The *labium* or *theca* forms the principal part of the haustellum. Its wall consists of a loose, flexible membrane, thickened on the anterior and posterior parts into definite plates. The plate on its posterior aspect, the *mentum* or *thyroid* (ment.), covers the whole ventral surface. It is a deeply pigmented, strongly chitinised, cup-shaped plate. Two short, weakly chitinised curved rods articulate to the lower end of the mentum. These rods are called the *mento-furcal bars* (m.f.b.). Their distal end articulates with the lateral processes of the *furca*, an important structure in the base of the oral disc.

The plate on its anterior surface forms the walls of a deep longitudinal groove, the *labial gutter*. The central portion of this plate, forming the floor of the gutter, is thin, especially in its distal two-thirds. Its upper third and its edges are strongly chitinised. This plate is called the *hypoglossa* (hyp. gl.) or *stomal plate*. The strongly chitinised edge of the two plates must be homo-
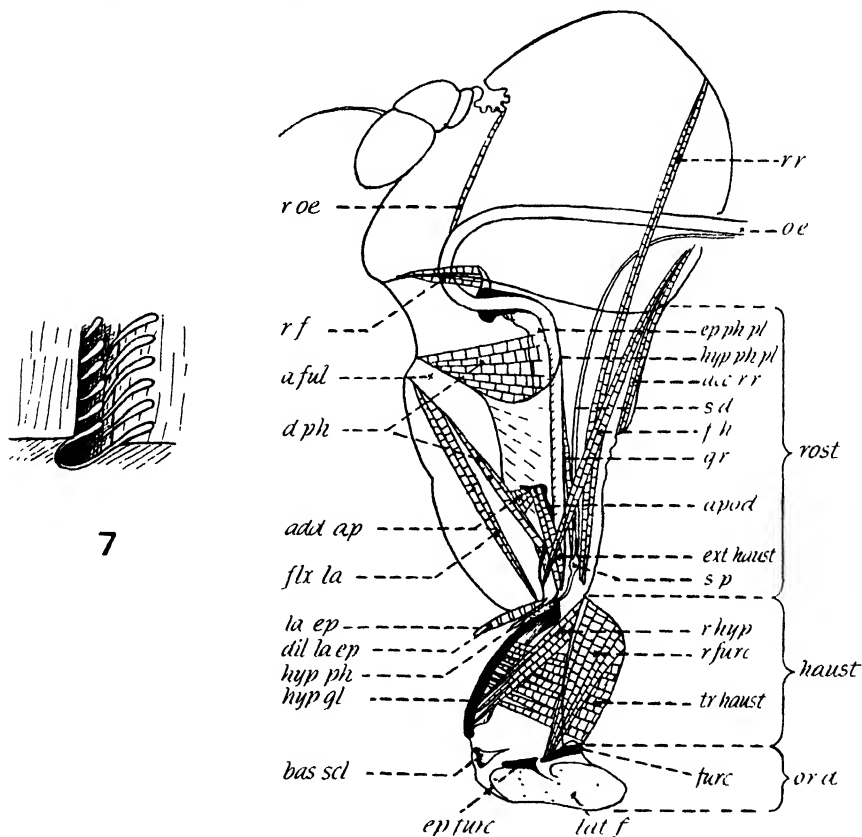
FIGS. 7-8.—7. *S. unicornis*, pseudotracheae; 8. *S. unicornis*, longitudinal section of the head, from the left.

logous to the two lateral bars which are described by Lowne and Graham-Smith in the blow-fly. Lowne has named these bars the *paraphyses*. The paraphyses terminate in a notched, articular head. In their distal end the paraphyses are pressed together so that the hypoglossa forms a closed tube.

The *labrum-epipharynx* (fig. 6, A, and figs. 4, 5, 8 and 9, la. ep.) is a little tongue that covers a little more than the upper third of the hypoglossa. Its upper end is attached to the border between the rostrum and the haustellum. The border of the tongue is surrounded by a chitinous band which proximally articulates with the apodemes. On its ventral side a deep groove stretches from its base to its tip. This groove continues the dorsal wall of the pharynx; the walls are chitinised. The chitinised wall of the groove fuses in its distal end

with the lateral chitinous band. The *hypopharynx* or *ligula* (figs. 6, B, and 8, hyp. ph.) is a little folded, chitinised blade underneath and is surrounded by the labrum-epipharynx, of which it is only one-half in length. It forms an elongation of the ventral wall of the pharynx and is pierced by the salivary duct. Proximally it is produced into two cornua that articulate with the cornua in the ventral end of the fulcrum.

The *oral disc* (figs. 4 and 5) forms the terminal part of the proboscis. It is a soft organ that surrounds the *discal sclerite*—a sclerite formed like a horse-shoe the two arms of which articulate with the notched head of the hypoglossa. From the discal sclerite radiate the *pseudotracheae* (fig. 7). The pseudotracheae are six pairs of fine grooves, the walls of which are strengthened by fine arches of unpigmented chitin. The two ends of the arches are free of the disc. By their simple form in *Scatophila unicornis* these organs do not differ from other described EPHYDRIDAE. When the fly desires to suck up a thin layer of fluid, the pseudotracheae are brought into contact with the surface on which the fly is feeding.

The ventral surface (the back) of the oral disc is covered by a pair of weakly chitinised, hairy plates, the *lateral folds* (lat. f.). A strongly chitinised arch is seen above the lateral folds following the border between the haustellum and the oral disc. This arch is the *furca* (furc.). It is composed of three parts firmly connected with each other. These parts are the *body* which stretches transversally along the lower end of the mentum and the *lateral processes*. As already mentioned, two little rods, the *mento-furcal bars* (m.f.b.), connect the mentum with the furca. Two small bars are seen a short distance from the lateral process of the furca and pointing in the same direction. These are the *epifurcae* (ep. furc.). A fine strand stretches from the rear end of the epifurcae into the lateral folds. Laterally, in the oral disc near the notched head of the paraphyses of the hypoglossa, are seen two little triangular plates. These plates are the *basal sclerites* (bas. scl.) of the disc. A fine strand expands between the basal sclerites and the epifurcae.

When at rest, the oral disc is folded along the middle so that the two halves of the surface containing the pseudotracheae are laid against each other. The oral disc is partly withdrawn into the haustellum.

THE MUSCLES OF THE PROBOSCIS (figs. 8 and 9).

(1) *Muscles arising in the head capsule.*

The *retractors of the rostrum* (Lowne) (= *retractors of haustellum*, Hewitt, 1914 : 59) (r.r.) arise from the occiput. By dissection, it has not been possible to state exactly where they arise. They are long and slender and lie on either side of the middle line behind the fulcrum. They are inserted into the skin of the rostrum near the border of the haustellum. In the blow-fly, they are inserted into the sesamoid sclerites. There are no such sclerites in *Scatophila unicornis*.

The *accessory retractors of the rostrum* (Lowne) (= *retractors of the rostrum*, Hewitt, acc. r.r.) arise ventro-laterally of the occipital foramen. They are inserted at the middle of the back of the rostrum.

The *flexors of the haustellum* (Lowne and Hewitt) (f.h.) arise ventro-laterally of the occipital foramen, near the accessory retractors of the rostrum. They are long, slender muscles which are inserted at the lower end of the apodemes. They serve to flex the haustellum to the anterior surface of the rostrum.

The *retractors of the fulcrum* (Lowne and Hewitt) (r.f.) arise from the anterior edge of the genae and are inserted at the cornua in the upper end of the fulcrum.

Their contraction causes the upper cornua to be drawn forwards and downwards. This again causes the lower end of the proboscis to describe a circular arc backwards.

The retractor of the oesophagus (Graham-Smith) (= *retractors of the fulcrum,* Lowne) consists, so far as I can see, of a single muscle fibre extending from the frontal sack to the oesophagus.

(2) *Muscles arising in the rostrum.*

The dilatators of the pharynx (Lowne) (d. ph.) arise from the internal surface of the anterior arch and lateral plates of the fulcrum and are inserted on the median ridge of the anterior (the dorsal) plate of the pharynx. The muscle fibres from the anterior arch are inserted at the upper part of the median ridge, while the muscle fibres of the lateral plates are inserted on the lower part of the median ridge and at the transverse ridge.
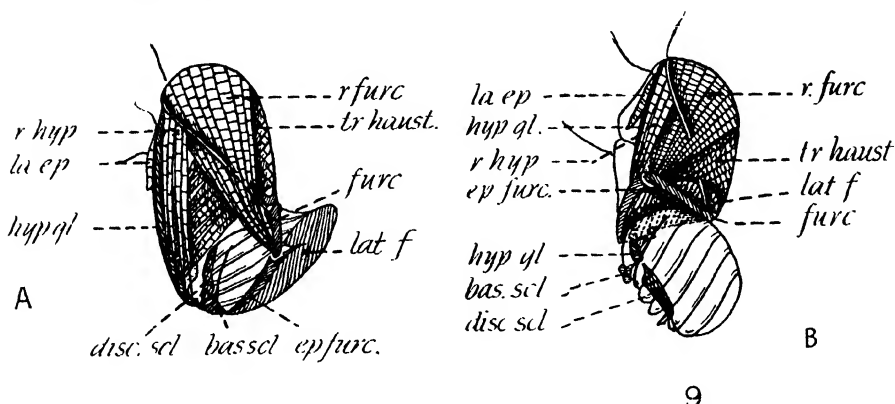

Fig. 9.—*S. unicornis,* the haustellum and the oral disc: A, in resting position and B, fully expanded.

The adductors of the apodemes (Graham-Smith) (= *retractors of the haustellum,* Lowne; *Accessory flexors of the haustellum,* Hewitt) (add. ap.) arise from the anterior distal margin of the lateral plates of fulcrum and are inserted on the *inner side* of the head of the apodemes. According to Graham-Smith they " seem to assist the extensors of the haustellum by adducting the heads of the apodemes."

The extensors of the haustellum (Lowne and Hewitt) (ext. haust.) arise from the cornua in the lower (distal) end of the fulcrum and are inserted on the *outer side* of the heads of the apodemes. They extend the haustellum on the rostrum by pushing down the apodemes.

These two muscles are very difficult to see because of the structures they overlie. The description is based upon that made by Graham-Smith 1930.

The flexor of the labrum (Lowne and Hewitt) (flx. la.) arise from the lower (distal) end of the anterior arch of the fulcrum and are inserted at the proximal end of the lateral chitinised borders of the labrum-epipharynx near their articulation at the apodemes. By the help of these muscles, the fly is able to lift the labrum-epipharynx from the surface of the haustellum.

The gracilis muscles (Lowne) (gr.) are a pair of very fine muscles that arise from the middle of the ventral plate of the fulcrum and are inserted on the

B 2

anterior wall of a tiny *salivary pump* (s.p.) on the *salivary syringe* (s.d.).   They regulate the flow of saliva.

The epipharyngeal muscles (Graham-Smith) are some fine muscle fibres, described by Graham-Smith, in the blow-fly.   According to him, they arise from the hypopharynx and the free portion of the salivary canal and are inserted on the walls of the neighbouring air-sacks of the rostrum.   He supposed that they assist in the deposition of the parts during flexion and extension. By the simple dissection used for this study of *Scatophila unicornis* it was not possible to see these muscles.

(3) *Muscles arising in the haustellum.*

The retractors of the hypoglossa (Bolwig) (= *the retractors of the paraphyses*, Graham-Smith) (r. hyp.) arise from the border of the proximal part of the mentum and are inserted by several slips into the distal end of the strongly chitinised border of the hypoglossa.   Their contraction causes the hypoglossa to be drawn upwards and inwards into the haustellum.   This again causes an extension of the oral disc.   They work together with the transverse muscles of the haustellum.

The retractors of the furca (Lowne and Hewitt) (r. furc.) arise from the proximal halves of the inner surface of the mentum and are inserted at the lateral processes of the furca.

Contraction of these muscles causes the surface of the oral disc carrying the pseudotrachea to be folded out.   The action is brought about by the arms drawing the epifurcae, and with them the lateral folds, upwards and backwards.   This causes the edges of the oral disc to describe an arc of a circle outwards and thus they expand the inner (dorsal) surface of the oral disc.

The transverse muscles of the haustellum (Lowne) (= *dilatator of the labium-hypopharynx*, Hewitt) (tr. haust.) arise from the middle line of the mentum between the centre and the distal end and are inserted at the strongly chitinised borders of the hypoglossa.   Their contraction causes the hypoglossa to be drawn towards the mentum.   This causes the extension of the oral disc.

The dilatators of the labrum-epipharynx (= *praelabral*, Lowne) (dil. la. ep.) are very short muscles arising from the chitinised borders of the labrum-epipharynx and are inserted in the chitinised walls of the median groove on its ventral surface.   They are believed to regulate the diameter of the groove.

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THE EFFECT OF PYRETHRUM ON THE SPIRACULAR MECHANISM OF INSECTS

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IT has long been recognised that pyrethrum acts primarily on the nervous system of insects. Krüger (1931) showed that the ganglia and nerves of *Corethra* larvae exposed to pyrethrum become vacuolated. Wilcoxon and Hartzell (1933) describe various degenerative changes in the ganglia of meal-worms treated with pyrethrum; and Hartzell (1934) confirmed these observations on *Melanoplus*. Recently F. H. Drummond (unpublished), working at the Imperial College of Science, has made a thorough histological study of these changes.

In the course of the present work sections of the thoracic and abdominal ganglia of normal adults of *Rhodnius prolixus* were made and their appearance compared with that in adults which, though still alive (as indicated by the action of the heart and the gut and by occasional movements of the legs), had been paralysed by treatment with pyrethrum 10 days previously. Fig. 1 shows approximately corresponding areas in the ganglia. In the pyrethrum-treated insect (fig. 1, B) the ganglionic mass is greatly shrunken, few cells are recognisable, and the greater part consists only of amorphous, granular material containing a few scattered vacuoles.

This destructive action on the central nervous system is reflected in the paralysis of the insect. Within a few minutes of the application of the pyrethrum to the cuticle, the movements become unco-ordinated, and within a few hours almost all movement ceases.

The cause of death in insects poisoned by pyrethrum is unknown. Since, however, it is a nerve poison, it seemed likely that it might lead to paralysis of the spiracular sphincters, the muscles of which are controlled by the central nervous system. In the living insect these sphincters are held closed most of the time; after death they are relaxed and open. Their chief function is to prevent loss of water by evaporation from the tracheal system : if they are caused to open by exposure to air containing 2 per cent. or more of carbon dioxide the insect loses water at a rapid rate (Mellanby (1934), Wigglesworth and Gillett (1936)) and, in a dry atmosphere, it quickly dies.

It therefore occurred to me that the cause of death from pyrethrum might be desiccation as the result of interference with the spiracular control. Two methods were employed to test this possibility. The loss of weight in insects poisoned with pyrethrum was compared with that in normal insects, and the movements of the spiracular sphincters were observed directly.

LOSS OF WEIGHT AFTER TREATMENT WITH PYRETHRUM.

A number of adults of the large blood-sucking bug *Rhodnius prolixus* were fed, and twenty-four hours later the anus of each was occluded with paraffin wax in order to prevent loss of water by excretion. Half were treated with pyrethrum and half kept as controls, both lots being exposed to 0 per cent.

relative humidity at 25° C. and weighed daily. An extract of pyrethrum in a highly purified liquid paraffin, containing 2 per cent. pyrethrins, was applied as a thin film to the antennae. Within half an hour the movements in the treated insects become unco-ordinated. After one hour unco-ordination is complete; the bugs are unable to walk properly, and spasmodic contractions of the muscles occur. At the end of twenty-four hours the insects are almost incapable of any movement, and sometimes they can be recognised as living only by the pulsations of the heart. In this state many will survive for ten or twenty days, others die after two or three days.

<div align="center">TABLE I.</div>

Loss of weight in milligrams on successive days after commencement of experiment.

Days	1	2	3	4	5	6	7
Pyrethrum treated	3·3	3·5	*8·2*	*9·4*	*9·4*	*9·4*	*8·0*
	4·9	3·2	3·4	2·2	2·2	2·2	1·8
	5·1	3·5	*8·5*	*8·5*	*8·5*	*8·5*	
	5·2	1·5	7·5	7·5	7·5		
Normal controls	1·8	2·2	1·7	1·7	1·7	1·8	
	0·8	3·0	2·0	0·9	0·9	0·9	2·2
	1·9	2·1	1·0	3·3	3·3	3·2	

Table I shows typical examples of the changes in weight in these insects. The figures in italics represent weighings made after death as indicated by the cessation of the heart beat. During the first day the loss of weight in the pyrethrum-treated insects is sometimes rather greater than in the normal. Perhaps this is due to the spasmodic muscular contractions during the early stages of poisoning; for it is well known that muscular activity leads to more frequent opening of the spiracles (Hazelhoff (1927), Wigglesworth (1935)). But thereafter the loss of weight does not differ from the normal until death has occurred. It then shows a two- or three-fold increase to 7·5 or 9·4 mg. per diem. Under conditions approximately the same Wigglesworth and Gillett (1936) showed that *Rhodnius* adults in which the spiracles are kept permanently open by exposure to dry air containing 10 per cent. of carbon dioxide lose from 9 to 12 mg. per diem, the total weight of the insect varying with the amount of blood in the stomach from 100 to 200 mg.

From these results it is evident that the loss of water by evaporation does not become excessive in insects treated with pyrethrum until *after* death.

MOVEMENTS OF SPIRACLES IN INSECTS TREATED WITH PYRETHRUM.

The opening and closing of the spiracles in the living insect is most readily observed in the flea examined by transmitted light (Wigglesworth, 1935). But it is difficult to apply pyrethrum to the flea without contaminating the whole body including the tracheal system. For the present purpose the adult bed-bug *Cimex lectularius* has therefore been used.

Fig. 2, A, shows the closing mechanism in the spiracle of *Cimex*, which is on the same principle as that described by Mammen (1912) in *Pyrrhocoris*, and fig. 2 B, B' shows the spiracle in the open and closed positions as seen by transmitted light in the living insect. The opening and closing is not always so easy to observe as in the flea, but in some specimens at least the exact degree of opening can be clearly seen.

In the normal adult *Cimex* the spiracles remain closed for the most part,

and make only slight quivering movements which open a minute cleft in the spiracle from time to time. They open widely in about a minute and remain open, if the insect is submerged in water. When the bug is examined in the gas chamber previously described (Wigglesworth, 1930, 1935) in air containing 10 per cent. carbon dioxide, they open fully.
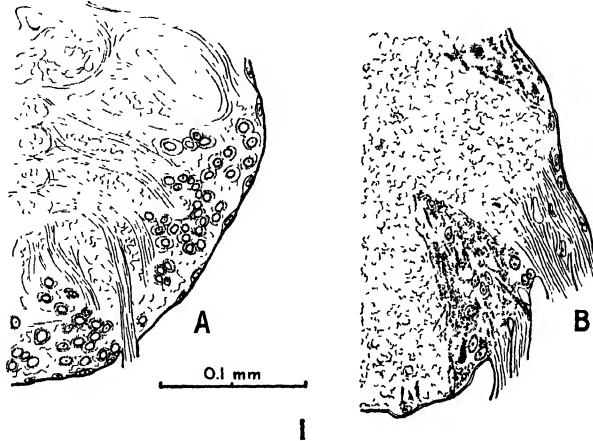

FIG. 1.—Horizontal sections through the fused abdominal ganglia of *Rhodnius prolixus* adult. (Fixed Carnoy, cut in celloidin and paraffin, stained haematoxylin.) A, normal adult. B, living adult paralysed 10 days with pyrethrum in liquid paraffin applied to antennae.
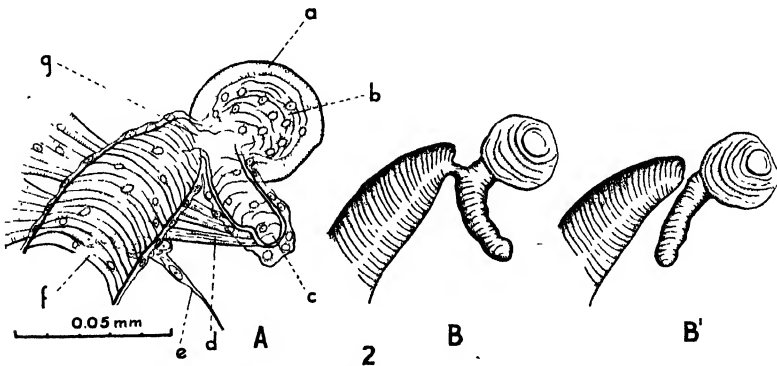
FIG. 2.—A, closing mechanism in abdominal spiracle of *Cimex lectularius* viewed from inside. *a*, peritreme; *b*, atrium; *c*, thick-walled diverticulum serving as a lever to close the tracheal orifice; *d*, muscle running from tip of lever to cuticle of abdominal wall; *e*, nerve, ending in group of cells applied to the muscle; *f*, trachea; *g*, tracheal orifice. B, spiracle as seen by transmitted light in the living insect, open position; B', the same, closed position.

A thin film of the same pyrethrum extract as before was applied to the antennae of *Cimex* adults. They were quickly paralysed; after twenty-four hours *very* slight movements of the limbs might be seen on watching closely; but the movements of the heart and gut continued normally and the insect might remain alive for a week in this state. Others treated in the same way died in two or three days.

During the early stages of paralysis, when spasmodic twitchings of the muscles are taking place, it sometimes seems as though the spiracles are opened rather more widely than in the normal insect. But later, when paralysis is complete, they show little movement, remaining closed most of the time. On flooding with water or on exposure to 10 per cent. carbon dioxide the spiracles slowly open and remain open until restored to air. After death the spiracles open.

DISCUSSION.

It is thus clear that at a time when the insect is almost completely paralysed and when histological examination of the nervous system shows that extreme degeneration has taken place in the ganglia, the spiracles are still functional. They are held closed and prevent evaporation of water; and they open in response to the usual stimuli. It is possible that the sensitivity of the response is reduced, but this has not been established.

It is worth recalling in this connection that Hazelhoff (1927) showed that the isolated spiracle of the cockroach will still respond to carbon dioxide, and in the flea (Wigglesworth, 1935) slow responses in the spiracle can be obtained after the central nervous system has been completely removed.

The cause of death after pyrethrum poisoning therefore remains obscure. Where an insect requires food at frequent intervals it may well die of starvation in its paralysed state. But there must be some general poisonous action in addition, for *Rhodnius* treated with pyrethrum will die in from 2 to 20 days; whereas the normal insect will resist starvation for 10 weeks or more.

SUMMARY.

The destructive action of pyrethrum on the central nervous system of insects is confirmed. But it is shown that in *Rhodnius* there is little or no increase in evaporation from insects paralysed with pyrethrum until after death; and that in paralysed *Cimex* the spiracles are kept closed and still react to carbon dioxide. Desiccation cannot therefore be the main cause of death after pyrethrum poisoning.

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THE SHAPE AND DISTRIBUTION OF THE FACETS IN AN ARTHRO-POD'S EYE AND SYSTEMS OF POINTS ON THE SPHERE

By Hans KALMUS and Anton E. MAYER.

(Department of Biometry, University College, London.)

Communicated by Dr. V. B. WIGGLESWORTH, F.R.S.

THE irregularity in the shape and distribution of the facets of an arthropod's eye are considered in the literature from the point of view of division of labour, or as inherited anomalies. In the first case the interrelation between the size of the facets and the optical acuity in the different regions of the field of vision are investigated (Plate, 1926), in the second case deviations from an intuitively conceived regular form. Such investigations are made under the assumption that regular distribution and shape of facets are possible. Some authors, especially in older morphological treatises, dwell on the great regularity of the hexagons. Closer investigation cannot accept " regularity " without defining it. We have tried to crystallise the intuitive conception of regularity, and plausible definitions can be made; but it appears then that completely regular figures of facets cannot exist at all. A limited regularity leads to configurations which might be suitable to describe the actual distribution. It appears that places of disturbance must necessarily occur, which corresponds to the observation. The geometrical formulation of the problem is of mathematical interest apart from its morphological application.

Two remarks concerning the physiology and development of a facet eye might be useful :

The physiologist expects for reasons of economy that a mosaic apparatus produces an image which is composed of little images as similar in size as possible and as closely packed as possible. Apart from the privileged parts of fields of vision referred to above such a mosaic of images is produced by an aggregation of many equal and maximally packed single eyes, the surfaces of which are the corneal facets of the complex eye. For the purpose of this paper the spatial configuration of the coniform single eyes towards the centre of the total eye can be neglected.

During the development of the facet eye in a holometabolic insect, for example a fly, the subdivision and differentiation of the ommatidia take place in one single developmental phase more or less simultaneously. In a hemimetabolic insect, for example a stick insect, younger larvae show fewer facets in the eyes than older larvae and imagines. The accrescence starts from several centres of growth which are situated on the margin of the eye during the single steps of metamorphosis. In both cases a larger number of facets grows " simultaneously." It is possible to regard the final shape and distribution of the facets as a result of the competition between the single growing ommatidia.

The simplest mathematical approximation of an insect's eye is presumably a subdivision of the surface of the sphere, or of a reasonably large section of it,

into a network. The lines of the network represent the border lines of the corneal facets and meet in the meshes of the net. We call such a curved figure as we draw it on the sphere, a polyhedron. In general its surfaces, the facets, are hexagonal. One might think that the problem is to draw a hexagonal polyhedron on this sphere. Now it is probably since the time of Plato but certainly since that of Euler, well known (Steinitz and Rademacher 1934) that hexagonal polyhedrons on the sphere do not exist. But this theorem does not touch our problem. In fig. 1 may be seen a part of a plane covered with hexagons, and it is naturally possible to regard this as a projection of a piece of a sphere's surface. Euler's theorem concerning the non-existence of hexagonal polyhedra anticipates that in each corner three or more edges meet. The marginal polygons in fig. 1 must therefore be regarded as pentagons, one side of which has got a bend. The whole is a " topological " problem and the more or less regular form of the lines and faces is unimportant.

Our problem, however, is a metrical one; it is easy to demonstrate, and well known, that the surface of a sphere cannot be covered with regular hexagons. The angle of a regular spherical hexagon is bigger than 120° and the surplus is $\frac{1}{6}$th of the area of its face. Regular hexagons of equal or different sizes can therefore be arranged on the sphere only in such a way that only two have a corner in common. One could, of course, distribute equal regular hexagons on the sphere which would not touch each other, but that cannot possibly be a model of an insect's eye. An absolutely regular distribution would demand that the centres of the hexagons are regularly distributed, leaving aside the problem of how the hexagons are placed around these centres, and what is to be regarded as a centre, for example the centre of gravity.

By implication also the limits of the single eye which results from the competitive growth already mentioned must at first be omitted.

The first question is therefore : Is it possible to distribute n points absolutely regularly on the sphere ? This question occurs also if one tries to produce an intuitive model of the lines of force radiating from a pole.

A first proposition : to regard the corners of a regular polyhedron as regularly distributed on the circumscribed sphere gives a solution only for
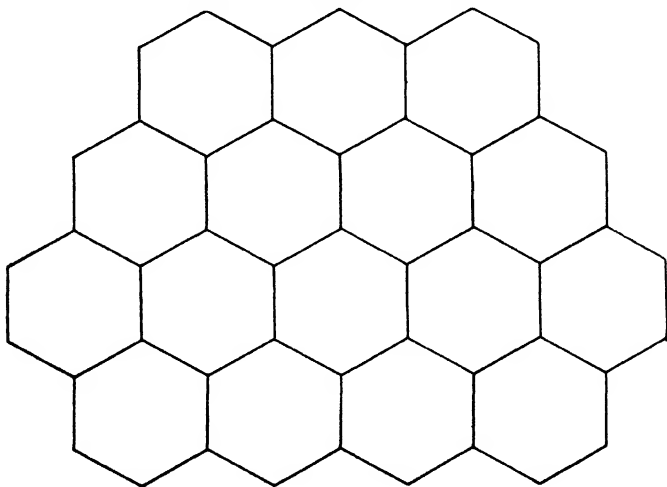
$n = 4, 6, 8, 12, 20$, in addition to the dihedrons (doubly covered regular poly-gons) which anyway are unsuitable for a large value of n : in a dihedron all points accumulate on the equator and there is nothing around the poles. Although there exist eyes consisting of only a few facets (the ant *Solenopsis*, 6–9 facets; the silver fish *Lepisma*, about a dozen facets) the number of facets is generally large, sometimes very large (the dragonfly *Aeschna*, 10,000 facets, the beetle *Necrophorus*, 30,000). Therefore the theory cannot remain confined to five single values of n, and another approach to the problem must be tried.

By geometrical abstraction we perceive that the centres of the spherical discs grow simultaneously and with equal speed and that they stop growing when the maximum radius is reached. Therefore we do not postulate *a priori* a " regular " distribution as was done by Finsterwalder [1] (1936). This defini-tion can be put in several other ways :

Spherical discs of equal size are placed on the sphere in such a way that they do not overlap and the uncovered surface becomes a minimum.

Or : n points on the sphere determine $\frac{1}{2}n \ (n-1)$ distances measured as shortest distances between the centres.
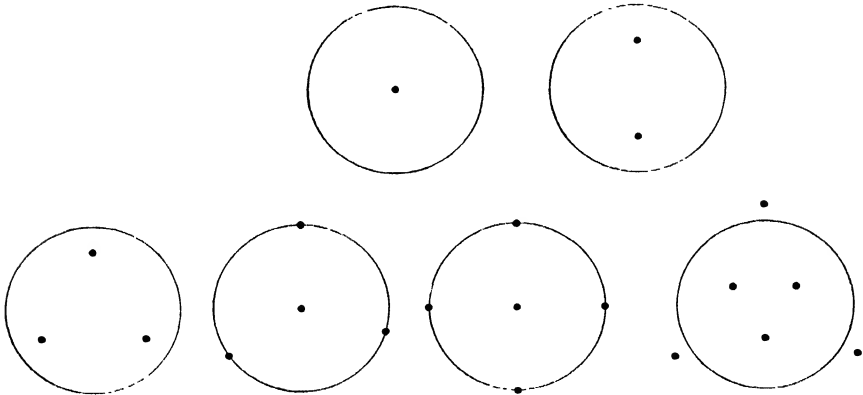
2

How are the n points to be arranged so that the shortest of the distances is a maximum ? (Blumenthal, 1939).

These definitions are rigorous forms of what we called, starting from bio-logical considerations, " as similar size as possible " and " as closely packed as possible." The last definition is the most practicable. It is also possible to take instead of the complete sphere a reasonably limited section of it, for example, a region ("Gebiet") in the geometrical sense corresponding to the real complex eye. In this form our problem is a generalisation of a problem described by Fejes (1940), who deals with an analogous problem for a large n in a plane region. A similar problem can also be found in a publication by Kershner (1939); the covering of a region with circles of equal and maximally small circles which of course do overlap.

The problem of locating n points the minimum distance of which reaches a maximum has always a solution; sometimes, for example when $n = 5$, several solutions. It is presumably very difficult to find a general solution for

[1] Finsterwalder chiefly considers distributions in which no point of the system is outstanding.
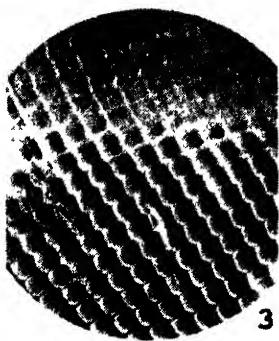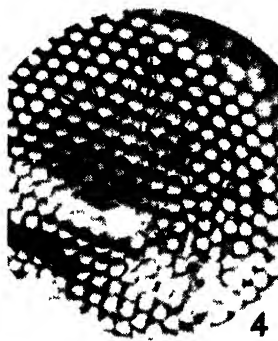
all values of n, and maybe it is as impossible as the exact description of the growth of a number-theoretical function. A description of the solutions for $n = 2, 3, 4, 5, 6$, and 7 follows and $n = 8, 12$, and 20 will be touched on (fig. 2).[2]

Fig. 2 gives the solutions in stereographical projections (central projection from the north pole towards the equatorial plane). The circle is always the equator, one point of the system is in the north pole and its projection therefore disappears to infinity. One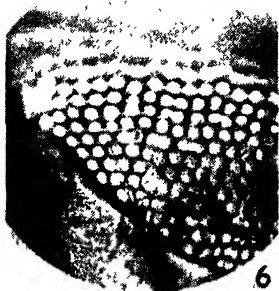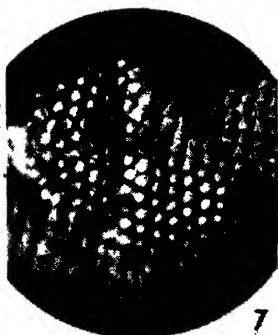 of the points nearest to the pole is placed in the 0 meridian. For $n = 3$ the solution is an equilateral triangle; for $n = 4$ the points are at the corners of a regular tetrahedron (in accordance with Blumenthal), for $n = 5$ the solution consists of the north and south poles and three points on the equator which are at least a quadrant distant from one another. The solution for $n = 6$ is the corners of an octahedron; for $n = 7$ for the first time greater difficulties are experienced, the minimum distance is the side of an equilateral spherical triangle the angle of which is 80°. The most likely solution for $n = 12$ is the corners of a regular ikosahedron.

The solution for $n = 8$ is not the corners of a cube which do not give the maximum of the minimum distance. The corners of an Archimedean Antiprism with square bases are nearer the solution or perhaps the solution itself. Analogous to this, the solution for $n = 20$ is not the corners of a dodecahedron. Details from a geometrical point of view will be published later.

TABLE 1.

n	Maximum of the minimum angular distance
2	180°
3	120°
4	109° 28′ 16″
5	90°
6	90°
7	77° 52′ 10″
8	74° 51′ 31″
12	63° 26′ 06″
20	45° 26′ 19″

It is certain that the configuration of maximal density for big values of n cannot be arranged in a net of equilateral triangles in the neighbourhood of every point. This configuration is only possible if one joins the centres of regular hexagons covering a plane. On the sphere the existence of exceptional places where the " Wabenzellen " have fewer than six sides is necessary. That can be proved as follows : The " Wabenzelle " round one point a of the system means the aggregate of all points which are nearer to a, or at least not farther from it, than from all other points of the system. We call a and b adjacent points if the corresponding cells have one side in common. The shape of the cells satisfies the presuppositions of Euler's theorem, mentioned on p. 16 : all boundaries are arcs of great circles. If we exclude systems, where all points are arranged on one great circle, which can be done for $n = 4$, no cell is constituted by two arcs of great circles. Then the following formula is valid (*see* Steinitz) :—

(i) $$3f_3 + 2f_4 + f_5 \geq 12 + f_7 + 2f_8 + \ldots$$

where $f_k =$ the number of cells with k corners. As in (i) the right side ≥ 12

[2] A limited number of arrangements in space is found in the covalencies of a polyvalent atom, resulting in a few stereochemical types (Sidgwick and Powell, 1940).

there must be at least 4 points on a sphere, which are adjacent to fewer than 6 points. Consequently, we expect on a whole sphere at least 4 centres of disturbance, where the points deviate from the triangular pattern and are arranged almost rectangularly. In these regions, where the network is only slightly different from a square one the Wabenzellen are hexagons with one pair of very short sides; consequently they possess rectangular appearances. On the surface of an arthropod eye covering the major part of a sphere, one or more of such regions must occur. This may be confirmed by observation. Fig. 3 shows a region of a complex eye of *Drosophila* where this configuration appears. In fig. 4 a piece of the surface of the same eye is reproduced showing the familiar hexagonal pattern. Fig. 5 shows both arrangements in a housefly.

It appears from these considerations that the configurations of facets in abnormal eyes due to mutation constitute a different problem. In the normal eye the forces involved are so well balanced that rougher local deviations from "regularity" do not appear, but disturbances in this balance occur in mutant races of several *Drosophila* species. In these the shape and arrangement of the facets is far from regular, polygons possessing more than six sides are frequent, and make possible the existence of polygons with fewer sides (figs. 6 and 7).

In conclusion we should like to express our thanks to Professor J. B. S. Haldane for his help and interest.

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BOOK NOTICE.

A Text-Book of Zoology. By T. J. PARKER and W. A. HASWELL. 6th edition in 2 volumes. Volume 2, revised by C. FORSTER-COOPER. 8vo. London (Macmillan) 1940. pp. xxiii + 758; 656 figs. Price 36*s.*

This is the second volume of a work noticed in the last volume of these *Proceedings*, and is devoted to the Chordata.

The general plan of this well-known work remains unaltered and new material has been added wherever it seemed best to fit.

A new classification of Fishes is introduced, and the former chapters on geographical distribution, the philosophy of Zoology, and on the history of Zoology are absent from this edition.

There is a remarkable list of periodicals of which the use is not clear and some entries are bad examples of "made-up" titles.

The index occupies 58 pages of treble-column matter.

AN INTERESTING CASE OF DEVELOPMENT IN CERTAIN SOUTH AMERICAN HESPERIIDAE (LEP. RHOPALOCERA)

By Brigadier W. H. Evans, C.S.I., C.I.E., D.S.O., F.R.E.S.

Some of the handsomest Hesperiids in the world appertain to the American subfamily Pyrrhopyginae and my interest therein was aroused by the investigations of Mr. E. L. Bell of New York, which appeared in 1931 (*J. N.Y. ent. Soc.* **39**). He found that in the *phidias* group of the genus *Pyrrhopyge* specimens apparently belonging to the well-known species *phidias* and *bixae* could be separated by the very different genitalia into 2 or 3 species and that in certain cases the genitalia of a *phidias*-like species exactly resembled those of a *bixae*-like species.
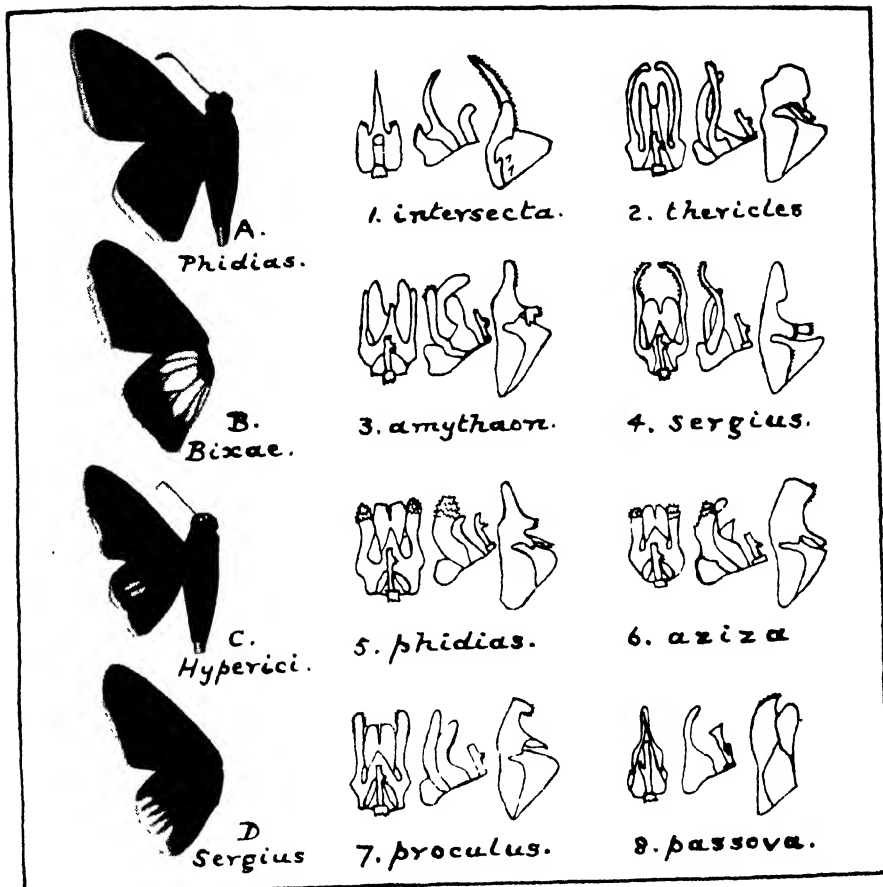
The group consists of large dark blue insects with a wing expanse of 2 to 2½ inches : they all have red heads and red tails to the abdomen and the cilia of the wings are usually pure white. There are four well-marked types of facies, viz. :

A. *phidias* : plain dark blue above and below.
B. *bixae* : resembling *phidias* above, but with a well-marked basal white band on the hind-wing underside.
C. *hyperici* : resembling *bixae* below, but with a large pale blue area on the upperside of the hind-wing.
D. *sergius* : resembling *phidias* above, but with a broad submarginal white band on the hind-wing underside.

I collected together some 650 specimens of the group in the British Museum in London and from the Zoological Museum, Tring. My investigations in respect of specimens of *phidias, bixae* and *sergius* types confirmed and extended Mr. Bell's results. He had found only one species of the *hyperici* type and I did not anticipate finding any more. My first dissection agreed with Bell's. As a check I dissected a second specimen which appeared to diverge in facies from the first more than did the rest of the series of 40 I had before me. Its genitalia were quite different so I dissected up the whole series and eventually found that there were 8 quite distinct species.

This, however, is by no means the whole story. I had obtained similar results in Oriental genera. For instance, in the genus *Potanthus* I had found many more than eight species looking alike, but with quite different genitalia. I found that every one of the genitalia was repeated in the *phidias* and *bixae* types, while three of them occurred in the *sergius* type. I then arranged examples of each form in horizontal rows according to the wing pattern and in vertical rows according to the genitalia pattern and came to the conclusion that there were 8 perfectly distinct species, each with 3 or 4 wing patterns.

I then found that the *hyperici* form of each species occurred only in Para and the lower Amazon region and that the other forms were absent in that area. Specimens from Guiana and eastern Venezuela were always conspicuously smaller, while the termens of both wings were excavate and the flanges on either side of the uncus were shorter. In British Guiana and eastern Venezuela the *phidias* type only occurred, while all specimens from French Guiana belonged to the *bixae* type. The *phidias* form occurs generally from Colombia to Bolivia, while one species (*phidias*) extends to Mexico, having slightly modified genitalia in Central America. The *bixae* form seems to occur

A.
Phidias.

1. intersecta.

2. thericles

B.
Bixae.

3. amythaon.

4. sergius.

C.
Hyperici.

5. phidias.

6. aziza

D
Sergius

7. proculus.

8. passova.

with the *phidias* form from Colombia to Peru, but generally the white band is very much wider in Colombia than it is in Ecuador, Peru and Bolivia. The *sergius* form seems to be confined to Peru, just reaching into Ecuador and Bolivia, but *phidias* forms from British Guiana show an approach to the *sergius* type, particularly in the species *phidias* : this tendency is entirely absent in specimens from Trinidad.

In the genitalia diagrams the left-hand figure in each case represents the central view of the uncus and the aedeagus. The central figure shows the uncus and the aedeagus viewed from the left. The right-hand figure shows the inside of the left clasp. It will be observed that the genitalia of No. 1 species, *intersecta*, are totally different in all respects from the genitalia of the other 7 species, and particularly so in respect of the aedeagus as shown on the right of the central figure. The wings in this species are rather more prolonged and there is a slight difference in the hind-wing venation about the lower end of the cell. I consider that the species should be separated generically from the remainder. There are several other species now included in the genus *Pyrrhopyge* which have very similar genitalia and would accompany *intersecta* into the new genus. Also, strange to relate, there are some species in what are considered to be widely separated genera, viz. *Jemadia, Mimoniades,* and *Sarbia,* which have similar genitalia and consequently should be considered congeneric with *intersecta*.

It will also be noticed that the genitalia of No. 8, *passova*, are entirely different from the rest : here again particularly in respect of the aedeagus, which is bifid. In this case there are other structural differences : the antennal club is differently shaped, the hind-wing is tornally lobed and secondary sexual characters are present in the legs. I have no hesitation in separating this species generically from *Pyrrhopyge*. All the forms can be at once separated from the remaining species by the presence of a conspicuous red area at the tornus of the hind-wing.

The *bixae* and *hyperici* forms of the first species *intersecta* can be readily distinguished by the extension of the hind-wing white band on the underside to the fore-wing. The same forms in No. 7, *proculus*, have a white basal streak along the costa of the fore-wing on the underside.

The *hyperici* forms for each species can be readily separated by the shape of the blue area on the upperside of the hind-wing as well as of the white area on the underside.

The *sergius* form of No. 6, *aziza*, has the submarginal white band on the hind-wing underside appearing also on the upperside.

For the remaining forms of each species dissection of the genitalia is the only certain means available for identification, though the amount of red colouring in the head and the blue shade of the ground-colour of the wings is often of assistance.

I can offer no explanation of the remarkable development which I have described. Perhaps there is something in the climate of Para that induces the blue coloration on the upperside of the hind-wing. Or the cause may be some chemical factor in the food-plant dependent perhaps on the geological formation. Since no Hesperiid, as far as is known, is " protected," I am afraid the mimicry theory cannot be applied. In this connection it may be remarked that many species of the PYRRHOPYGINAE are, shall one say, " mimicked " by species in other subfamilies of the HESPERIIDAE, the most noteworthy being a species of the genus *Pyrrhopygopsis*, which displays both *phidias* and *bixae* forms. This, however, is a very different subject, which cannot be discussed further at present.

MATING AND OVIPOSITION IN *CNEPHASIA CHRYSANTHEANA* (DUP.) (LEPIDOPT., TORTRICIDAE)

By J. A. REID, F.R.E.S.

SOME trials made by Dr. O. W. Richards had indicated that it was difficult to get species of *Cnephasia* to mate in captivity, at least in rather small containers. Therefore in the first attempts to secure mating of *C. chrysantheana* the moths were confined in as large a space as possible. A window embrasure 8 feet long, 5 feet high and 1 foot deep was chosen, the open side facing the room being closed with muslin. In this space freshly emerged females were found to mate fairly readily when left overnight with about an equal number of males; of 17 ♀♀ about 3 later proved infertile. The fertilisation of a female was shown by dissection and examination of the bursa, when the presence or absence of a spermatophore could be seen.

Since *C. chrysantheana* mated quite freely in the window embrasure, it was decided to try smaller containers, as the former was inconvenient to use. Subsequently when females were required for oviposition experiments they were put in a wooden box 2′ × 1′ × 1′ with a glass front, two sides of muslin, and a sliding door at one end. Altogether a total of 60 females were put in this box to mate, and of 54 recovered, 42 proved to have mated and 12 had not. Smaller containers were also tried in order to see if the size of the container affected the ease with which mating occurred and it was found that it did, as can be seen from Table I. Owing to the comparative scarcity of the males it was not always possible to get equal numbers of the sexes, and some of the males had mated once before, but as it is shown later that males can mate on two successive nights, the figures show that mating does not occur at all readily in small containers.

Attempts were made to get *C. virgaureana* (Treits.) and *C. pascuana* (Hb.) to mate but without success. *C. pascuana* was tried in the window embrasure; *C. virgaureana* was tried in the box, in large glass jars, etc., both indoors in the laboratory, in a constant temperature room and out of doors. Some of the females that were kept laid a few eggs, but these were infertile and dissection subsequently showed that the moths had not mated.

As soon as it was discovered that *C. chrysantheana* would mate in captivity it was decided to try and find out the egg number. For this purpose the following method was evolved. Females that had emerged during the previous 24 hours were put in the glass-fronted box mentioned earlier with about an equal number of males. The following morning the females were removed and placed singly in 3 × 1-inch tubes closed with corks that had two furrows cut in the sides to provide ventilation. A piece of cotton wool, on which a few drops of a strong cane-sugar solution had been placed, was pinned to the underside of each cork and a strip of blotting-paper put in each tube for the moths to oviposit on. The moths, though having rather short tongues, were seen to take the sugar-water freely, and the impression was gained that whenever they came in contact with it or very close to it, the tongues were extruded automatically as a reflex action. The great majority of the eggs were laid on the blotting-paper, and the strips were removed each day, the eggs on them counted, and fresh pieces put in the tubes. By counting the eggs on the blotting-paper and the few that were laid on the corks and the glass, it was possible to keep a record of the number of eggs laid by individual moths each night.

The strips of blotting-paper from the different days were kept apart so that the incubation period of the eggs could be determined. In a series that were given no sugar-water, the majority of the eggs were laid on the underside of the corks and not on the blotting-paper; evidently the moths given sugar-water were prevented from behaving similarly because of the damp cotton wool.

It was not possible to tell whether any eggs were laid in the box on the night of mating, so separate experiments were made to settle this point. A fresh pair of moths was put in each of two large glass jars (the dimensions of one are given in Table I) and the mouths of the jars closed with muslin. The following

TABLE I.

Container	No. of moths		No. fertilised after 2 nights
	♀♀	♂♂	
Glass jar, 1' high, 8" diam.	6	5	4
Zinc and glass breeding cage, 11" high, 7" diam. .	6	6	2
Glass jam jar, 1 pound size	6	3	2
7 glass tubes, 3" × 1", corked, 1 pair of moths per tube	7	7	1

morning the jars were examined and no eggs were found in either; one female was later shown to have been fertilised. The experiment was next repeated on a larger scale, 5 fresh females being placed in each jar and again no eggs were found the following morning, although 7 of the 10 females were later shown to have been fertilised. It was therefore concluded that no appreciable number of eggs is laid on the night of mating and that consequently the females laid all their eggs in the tubes. Presumably an appreciable time elapses between the placing of the spermatophore in the bursa and the completion of migration by the sperms from the bursa into the spermatheca. Possibly the time taken by this migration may account for the fact that no eggs are laid on the night of mating, although the examination of some spermatophores the morning after mating failed to reveal any sperms, which were, however, plentiful in the spermatheca.

The day-by-day oviposition record for 19 fertile females given sugar-water is shown in Table II, which also shows the total number of eggs laid by each moth and the length of life in days. The temperature was uncontrolled and varied between 17° and 21° C. After death each moth was dissected and the condition of the ovaries noted; the last column of the table gives the approximate number of mature eggs found in the ovaries. At the foot of the two previous columns the mean number of eggs laid by one moth (300) and the mean length of life 14·6 days are shown. The figures in this table should be compared with those of Table III, which records the same data for five fertile females that were not given any sugar-water; the differences are striking. The mean length of life of the starved moths was only about one-third that of the others and the mean number of eggs laid a little more than a half; the egg number was therefore less affected by starvation than the length of life. The values for the daily egg numbers of the starved females during the first three days are much the same as for those given sugar-water; there is one record of 110 eggs on the third day and there are only three records of over 100 eggs in a day from one moth of those given sugar-water. The last column of Table III shows that at death the ovaries of the starved moths were empty, or almost

TABLE II.

Oviposition, etc., in moths given sugar-water.

No. of ♀	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total eggs laid	Length of life in days	Approximate no. of mature eggs left in ovaries
									No. of eggs per day												
1	3	51	110	39	46	31	24	19	11	7	0	0	D0	1	1	D0			341	13	30
2	0	0	0	2	10	87	0	1	63	1	0	0	11	1	D0				177	16	60
3	32	40	43	27	23	33	14	15	15	12	18	7	5	D0	1	D0			284	14	6
4	68	7	35	55	69	49	24	24	10	7	30	12	10	D0					400	14	7
5	0	17	89	85	65	56	31	36	23	17	0	9	28	8	9	5	4	D0	482	18	2
6	28	33	0	0	2	21	33	9	32	3	24	20	20	37	25	11	0	D0	298	18	40
7	49	55	44	20	16	25	21	0	0	3	0	0	0	0	0	0	D0		233	17	40
8	65	51	64	47	46	30	27	27	17	17	13	15	15	10	11	D0			455	16	4
9	41	89	54	32	49	36	37	22	17	13	10	0	0	D0					400	14	3
10	1	2	4	17	114	52	28	30	14	26	11	3	D0						302	13	10
11	0	0	1	8	52	70	27	50	29	33	20	4	D0						294	13	20
12	0	0	0	2	47	90	0	0	0	0	D0								139	11	22
13	1	8	10	70	85	35	11	35	33	0	24	22	0	D11					315	14	6
14	1	48	49	38	28	23	23	21	5	15	12	6	8	7	D0				284	15	3
15	40	22	19	22	19	23	18	12	12	10	11	10	7	6	4	7	D0		261	18	12
16	2	4	8	0	10	102	40	18	9	4	D0								197	11	33
17	74	36	11	11	10	2	8	8	10	4	0	0	7	D0					181	15	40
18	33	67	57	44	30	31	25	28	15	21	27	15	16	10	D3				422	15	4
19	14	73	57	33	28	18	22	15	11	10	4	5	0	D0					290	14	—
Means																			300	14·6	—

D = died.

TABLE III.

Oviposition, etc., in moths not given sugar-water

No. of ♀	1	2	3	4	5	6	7	8	Total eggs laid	Length of life in days	Approximate no. of mature eggs left in ovaries
				No. of eggs per day							
1 . .	75	44	41	D6					166	4	10
2 . .	84	57	28	3	D0	6	2	D0	172	5	0
3 . .	35	77	110	59	8	6	2	D0	297	8	0
4 . .	72	30	7	D0					109	4	3
5 . .	59	50	16	0	0	0	D0		125	7	0
Totals per day .	325	258	202	68	8	6	2	0	Means		
									172	5·6	

D = died.

empty, of mature eggs, whereas there are no records of ovaries quite empty of mature eggs in Table II. This suggests that the starved moths laid all the mature eggs that were in the ovaries when they mated, but were unable to develop any of the immature ones, whilst those given sugar-water were able to do so. There is no doubt that this was so, for comparison of the appearance

of the ovaries after death in the moths given sugar-water, with the ovaries of a virgin female, showed that the upper part of the ovaries which contains immature eggs was much larger in the virgin female than in those given sugar-water, especially those which had laid 400 or more eggs. It follows from the above that presumably the mean number of mature eggs in the ovaries at the time of mating is approximately that laid by the starved females, namely 172. Unfortunately this was not checked by dissection as there were no more virgin females available when the idea occurred to me. The potential number of eggs in the ovaries of a freshly mated female that was dissected was estimated at about 500. It may be remarked here that each ovary is composed of 4 ovarioles, each containing mature eggs in the lower third and increasingly immature eggs as one passes along the upper two-thirds; each ovary is bent twice on itself and thus divided into three parts.

It will be seen from Table II that on the whole the moths which laid the fewest eggs had the largest number of mature eggs remaining in the ovaries at death, and *vice versa.* If it is assumed that these mature eggs remaining in the ovaries would have been laid had the moth lived longer, one can say that the potential egg number was less variable than the actual number laid; this varied from 139 to 482 with a mean of 300. Five moths laid 400 or more eggs and it is probable that under the most favourable conditions the mean egg number would be nearer 400 than 300.

If the records for each moth in Table II are examined, it will be seen that the highest number of eggs laid in any one day was almost always during the first to fifth days of oviposition, regardless of when oviposition commenced; the mean falls at 3·4 days. With the starved females 4 out of 5 laid the highest number of eggs on the first day of oviposition and the mean is at 1·4 days; the total eggs per day shows a steady fall from a maximum value on the first day. If the corresponding daily totals are obtained from Table II, summing the values for the first, second, third days, etc., of oviposition, irrespective of when oviposition commenced, the nodal value falls on the third day instead of on the first, and the following figures are obtained: 483, 740, 879, 590, 659, 655, 421, 339, 248, 167, 193, 145, 92, 88, 50, 19, 7.

Of the total number of females employed in the egg-number experiments in which sugar-water was given, 8 proved to be unfertilised. The average length of life of these unfertilised females was the same as that of the fertilised ones (14·5 days), but the variability was a little greater; the shortest time being 10 days as against 11 in the fertile females, and the longest time 19 days as against 18. All the unfertilised females laid a few eggs, the lowest number being 9 and the highest 201 with a mean of 59. None of these eggs developed.

Some of the fresh males with which the females in the oviposition experiments were mated were also put separately in tubes with blotting-paper and sugar-water to see how long they would live. In order to be able to distinguish them from the older males after mating, a piece was clipped from the fore-wing of each of the fresh males before they were put in the box to mate. Thirteen males treated in this manner lived from 10 to 18 days, the mean length of life being 14·3 days.

As it had been noted that males put in with females on two or more nights seemed to die rather rapidly, an experiment was made to see whether males could mate more than once. Twelve fresh females were put in the box with six males that had emerged the day before and had already had one opportunity to mate. Eleven females were recovered and of these 5 were fertilised and 6 were not; the bursae in 4 of the 5 contained only small spermatophores. Evidently the males can mate on two successive nights, but apparently do not

mate more than once in a night; so far as can be ascertained in none of the matings carried out was the number of females fertilised greater than the number of males present.

Eggs and first stage larvae.

The eggs are soft somewhat irregular-shaped objects, roughly oval in outline, about 0·5 mm. long, pressed flat against the surface on which they are laid, and only moderately convex in profile. They may be laid in close groups of 50 or more, sometimes two layers deep; or singly. The moth usually covers them with a few scales from the end of the abdomen and with any other dust lying about, each egg having one or two threads of blotting-paper and some scales adhering to it. A moth that was observed ovipositing was seen to press the tip of the ovipositor against the blotting-paper while the egg was extruded, at the same time rapidly vibrating the last segments of the abdomen up and down; it seems probable that in this way the stout brush at the end of the abdomen was enabled to draw up a few strands of the blotting-paper over the newly laid egg.

When laid the eggs are a creamy buff in colour and smooth, but the appearance alters considerably with age. The colour darkens from buff through orange to orange-pink, attaining the maximum depth of colour by about the 6th day. The pink colour is dorsal and is not present on the underside of the egg or around the attached margin. At about the 6th day faint longitudinal furrows may appear on the egg and these may later develop into a network of acute ridges upon the egg; not all the eggs display these ridges, which are no doubt an effect of shrinkage. By the 13th day the ocelli of the embryo larva are just beginning to be visible and by the 16th day they are well developed as a pair of round black spots, and the pigmentation of the whole head and of the prothoracic plate is just becoming visible. Shortly before hatching the larva is plainly visible through the transparent chorion of the egg, lying curled up head to tail. The eggs hatched in 18 to 21 days, the majority on the 19th day; about 95% hatched. This was in the laboratory at a temperature of 17–21° C.

The larvae are about 1·0 mm. long and orange-yellow with a black head and prothoracic plate. The anal plate is the same colour as the body. Down the middle of the body in newly hatched larvae runs an orange-pink line which is evidently due to the presence in the gut of the orange substance from the egg; this darker line is not present in older larvae and the substance is evidently absorbed or voided.

A few hours after hatching the larvae begin to search for suitable places in which to hibernate until the following spring. They are strongly thigmotropic, and creeping into the smallest spaces possible they spin around themselves a small silken cocoon. Spinning up is completed in from 24 to 48 hours after hatching and apparently no food is taken in this time; a piece of *Heracleum* offered was left untouched.

Note by O. W. Richards.

After Mr. J. A. Reid had left for Malaya, the young larvae were hibernated in the tubes in an open summerhouse. They were brought indoors for examination at the end of March and in early April. The larvae then very rapidly left their hibernation cocoons and began wandering. Mr. J. A. Downes tried to get them to feed, using every device we could think of, but nearly all refused everything offered. A few seemed to make the beginning of a small mine, but this was not continued. All the several thousand larvae died in a week or two.

NOTES ON THE FOOD OF *MICROPEPLUS,* WITH A DESCRIPTION OF THE PUPA OF *M. FULVUS* ERICHSON (COLEOPTERA, MICROPEPLIDAE)

By H. E. Hinton, Ph.D., and F. L. Stephens, M.Sc.

(*British Museum (Natural History*).)

The family Micropeplidae contains only two genera, *Kalissus* Lec. with one species in western North America and *Micropeplus* Latr. with 24 species widely distributed in the holarctic region and one in Central America. Nothing has been recorded of the food of these beetles and the only description of their immature stages is that of Lubbock (1868) of the larva of *M. staphylinoides* Marsham (1802) which he found on the underside of dead boughs. According to Thomson (1862) the adults live almost exclusively in mud by the side of lakes and streams. Fowler (1889) recorded them in haystack and vegetable refuse and Ganglbauer (1899) under decaying vegetation, in mouldy wood, and in dung.

NATURE OF THE FOOD.

While collecting (12.i.1941) in a compost heap [1] in the grounds of Linton Village College, Cambridgeshire, five larvae, one pupa, and four adults of *M. fulvus* Erichson (1840) were taken. The adults and larvae were found about two feet from the top of the heap on or near the ground among very decayed and partly liquefied cabbage leaves and other plant refuse. The pupa was found in a small cell about an inch below the surface of the ground at the bottom of the compost heap.

To discover the food of the beetle, the following experiments were made. One adult was placed in a petri dish lined with moist filter paper and containing barley flour, preserved fig, bread, coffee, chocolate, and two common fungi, the common green mould (" *Penicillium glaucum* ") and the cultivated mushroom (*Psaliota campestris*). Next day the beetle was removed to a clean slide and its pellets collected. These contained some starch grains from the barley and *Penicillium* conidia. Faeces found in the petri dish were of similar composition. On the third day the beetle was dead, having become entangled in deliquescent chocolate.

The above experiment was repeated using two recently emerged adults (still pale brown in colour) and one mature adult. After the first day the faeces of the two immature beetles consisted of a mixture of *Penicillium*

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[1] This heap more or less fills a pit in the ground about ten feet square and three feet deep. This pit, according to the gardener, Mr. Jacob, has been used to decompose plant refuse for nearly two years. During the warmer parts of the year it is swarming with beetles, Staphylinidae, Trichopterygidae, Hydrophilidae (*Cercyon*), and Cryptophagidae (*Atomaria, Ephistemus*) being particularly numerous in individuals. In midwinter the beetle population is notably reduced, the Trichopterygidae, Hydrophilidae, and Cryptophagidae being absent or rare and the common summer Staphylinidae being replaced by a few mid-winter species such as *Quedius cinctus* Paykull (1790) and *Tachinus subterraneus* Linnaeus (1758). Larvae, pupae, and adults of *Q. cinctus* were rather abundant as were also larvae and adults of *T. subterraneus*.

conidia, *Psaliota* spores, and some starch and coffee. In these faeces the mushroom spores predominated. The pellets of the mature specimen consisted entirely of *Penicillium* conidia. The excrement of these beetles was examined daily for a week, and those of the mature beetle consisted almost entirely of *Penicillium* conidia, while those of the less mature specimens consisted of a mixture of the two fungi. One of these specimens, the most mature, was later fed on dry rot fungus (*Merulius lacrymans*), which it ate readily.

The *Penicillium* conidia in the excrement are at least partly digested. A microscopic examination shows that a proportion of the conidia have collapsed, while in others the walls are thin or even broken so that they have a crescent shape. When the pellets were kept in water at room temperature (65° F. $\pm$ 5°) approximately 15% of the conidia became swollen and put out germ tubes on the second and third days. *Penicillium* conidia taken from the same culture, but which had not been ingested by the beetles, did not germinate until the eighth day. This seems to show that, in the case of the 15% or so of the spores that survive ingestion, the time taken for germination is considerably decreased by passage through the alimentary canal of *Micropeplus*. A possible explanation of this phenomenon may be that in a small number of spores (about 15%) the walls are thinned by the enzymes [2] of the beetle but not killed, so that they are rendered more susceptible to external physical conditions, *e.g.* moisture. *Psaliota* spores that pass through the alimentary canal are also often broken.

To discover if *Micropeplus* will transmit fungi externally, two specimens were placed in a tube containing sterile medium. Two days later the tracks of their footsteps showing where they had walked were represented by small colonies of *Penicillium*.

In a wood near Linton one larva and five adults of *M. staphylinoïdes* were found (26.i.1941) on the underside of several specimens of *Polyporus squamosus*. Faeces of these were examined, and in both larvae and adults were found to contain bacteria, fungal hyphae, and the spores of the following fungi : *Penicillium* sp., *Cladosporium herbarum*, *Fumago vagans*, *Botrytis cinerea*, and hyaline spores possibly belonging to a Basidiomycete.

The two species do not appear to be carnivorous in either the larval or adult stages. The five larvae and four adults of *M. fulvus* were kept for 24 hours in a tube containing a few small Dipterous larvae, and at the end of this time showed no signs of having attacked each other or the Diptera. The single larva and five adults of *M. staphylinoïdes* were also kept for nearly 24 hours in a tube containing two Dipterous larvae, one small Staphylinid larva, and two specimens of the small Lathridiid, *Coninomus nodifer* Westwood (1839). At the end of this time they had apparently not attacked each other or the other species with them.

<div align="center">DESCRIPTION OF THE PUPA (figs. 1–3).</div>

Female : Length, 1·9 mm.; breadth (across broadest point of abdomen), 0·9 mm. Body obovate, moderately depressed. Cuticle white and clothed only with a number of erect, moderately long and stout setae (fig. 1). *Head* not visible from above or at most with eyes and part of vertex visible. Front moderately concave and eyes very prominent.

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[2] Cellulase has been recorded in a number of wood-eating beetles (Mansour and Mansour-Bek, 1934). It is also possible that the " fungus cellulose " of the walls of the conidia may be fermented by bacteria in some part of the gut, as has been shown to be the case in the larvae of some beetles (e.g. *Cetonia*) and in the wood-feeding cockroach, *Panesthia*.

Surface glabrous except for three long setae which arise from near middle top of eye. Antennae extending to posterior third or fourth of prothorax in a deep, concave area on ventral side. *Pronotum* with shape and impressions as shown in fig. 2; with eight setae on each side as follows : two near middle of anterior margin; four more or less evenly spaced on lateral margin; and two near basal margin, one near middle and one very near basal angle. Mesonotum without distinct impressions and with a single seta on each side of middle near posterior margin; elytra extending postero-laterally to about basal half of first abdominal tergite and on middle apical margin with a long, thick spine which is directed forwards and lies on the same plane as elytra. Metanotum without distinct
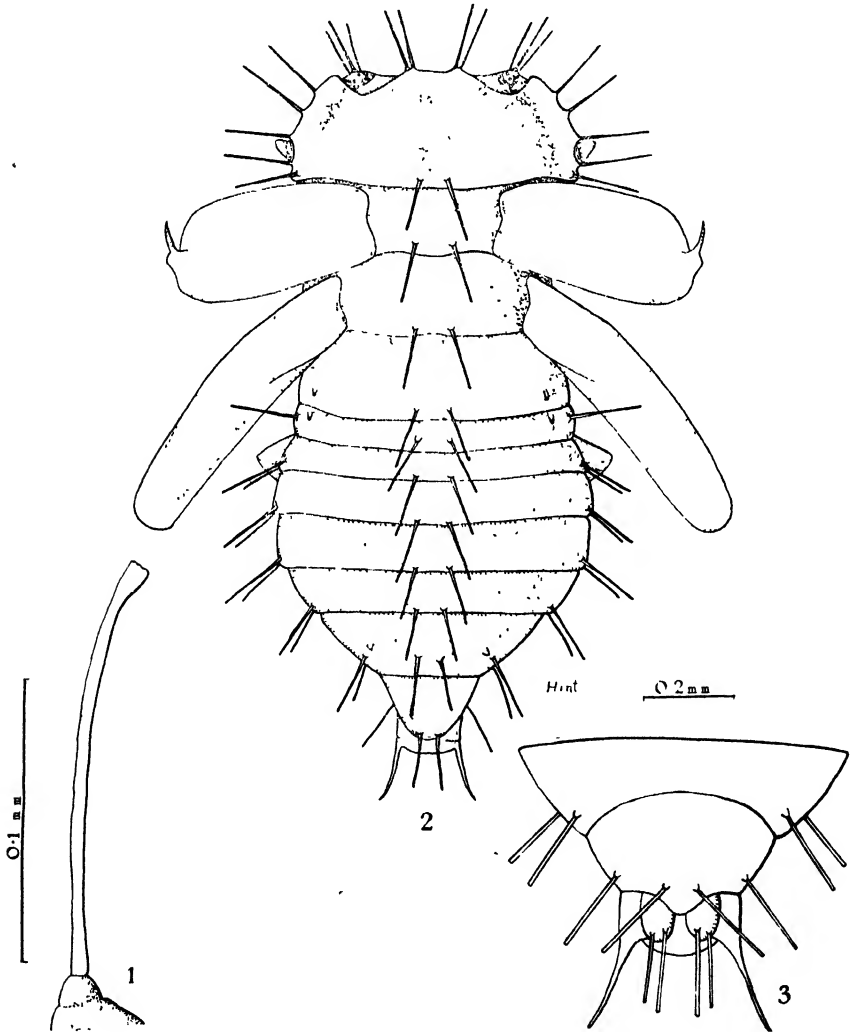
FIGS. 1-3.—Pupa of *Micropeplus fulvus* Erichson. 1. Pronotal seta. All setae when enlarged are similar in shape. 2. Dorsal view of pupa. Wings were partly extended in Pampel's fluid. 3. Ventral view of apex of abdomen of female.

impressions and with a single seta on each side of middle near posterior margin; wings extending posteriorly and ventrally to posterior margin of fourth abdominal sternite. Abdomen with first tergite very long and with a single seta on each side of middle near posterior margin; second tergite on each side with a seta near middle of lateral margin and one near middle half-way between anterior and posterior margin; third to seventh tergites setose like second but with lateral seta nearer posterior margin; eighth tergite nearly as long as broad, apical margin strongly rounded, and with a single seta on each side of middle; ninth tergite with each postero-lateral angle produced to form a long seta-like process. Abdominal sternites one to five with a single seta on each side near postero-lateral angle; sixth sternite (fig. 3) similarly setose and also with a seta on each side of middle near posterior margin. *Legs* with front pair extending to anterior margin of metasternum; tarsi separated by a distance equal to length of tibia. Middle pair extending to posterior two-thirds of metasternum; tarsi as widely separated as those of front pair. Hind pair extending to posterior margin of third abdominal sternite; apex of tarsi separated by a distance equal to their own length. Abdominal spiracles dorso-lateral and those of the first and second segments opening in apices of short, cylindrical, feebly sclerotised tubercles.

Specimen examined : 1 ♀, identified as *M. fulvus* by the adult characters which could be seen clearly through the pupal cuticle.

SUMMARY.

The larvae and adults of *Micropeplus fulvus* and *M. staphylinoides* feed almost entirely on fungi, particularly the spores and conidia, and are probably never carnivorous. About 15% of the conidia of *Penicillium* found in the faeces of the adults of *M. fulvus* had not been killed but were so affected that they germinated much more quickly than usual. *M. fulvus* is capable of the internal mechanical and external transmission of *Penicillium*. The pupa of *M. fulvus* is described.

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BOOK NOTICE.

Coconut Quest. The story of a search in the Solomon Islands and the East Indies. By J. S. PHILIPS. 8vo. London (Jarrolds), 1940. pp. 254, 30 pls., 4 figs. Price 16s.

This is a book by an entomologist called in by the owners to assist in preventing damage being caused to coconuts by the bug *Amblypelta cocophaga*.

The book is the story of the travelling involved and a description of the places visited, and it is written for the average reader. It is in fact more a travel-book than a work on Entomology.

It is well illustrated with many photographs of out-of-the-way places in the South Seas. The author visited many well-known entomological localities and gives a description of each place he visited.

THE RESTING POSITIONS OF BUTTERFLIES (LEPID. RHOPALOCERA)

By Brigadier W. H. Evans, C.S.I., C.I.E., D.S.O., F.R.E.S.

I am afraid the title of my communication is misleading. I can tell you nothing, which the majority of you do not know already, about the resting positions of British butterflies and they are adequately described in both Frohawk and Sandars books on the subject. My purpose is to ask you in your travels abroad to note and record anything abnormal in the resting positions of exotic butterflies, for the reasons which I will explain.

The ordinary butterfly on alighting assumes what may be called the alert position with the wings held vertical, pressed tightly together and the fore-wing well forward. When he feels secure he may proceed to open and close his wings, a frequent action when feeding or searching for food. Or he may bask with his wings flat. When he wants to rest, in dull weather or at night, he holds his wings erect, but with the fore-wing pressed well back inside the hind-wing : many sit with their heads down by day, reversing the position at night.

In the British butterflies there are two exceptions to the normal attitudes. The " Grizzly Skipper," *Erynnis tages* (L.) rests with his wings open, but folded right back like a Noctuid moth. The tawny skippers belonging to the genera *Hesperia, Ochlodes* and *Thymelicus* often bask with the fore-wings vertical and the hind-wings horizontal. In the tropics there is a large number of species belonging to the subfamily Pyrginae of the Hesperiidae which appear invariably to sit with their wings spread flat, some species alighting thus on the upperside of a leaf, others on the underside.

Now one of the most difficult problems I have ever had to tackle has been the classification of the Hesperiidae, as the differentiating characters available are very much fewer than in any other group of butterflies. Certain genera present some outstanding feature which appears to serve as the basis for a subfamily or a group of genera, but there remains a large number of genera difficult to place in any particular group. A knowledge of the early stages would of course help very materially, but here the information available is fragmentary and is likely to be acquired very slowly. It will be seen that information regarding an additional character, such as the resting position, might prove of the greatest service to the taxonomist. I ask therefore that collectors in the tropics should note, when they see a Hesperiid, whether it alights with its wings flat, above or below a leaf, and whether it rests noctuid-wise or with the fore-wing vertical and the hind-wings horizontal.

A MAP PROJECTION OF BIOLOGICAL INTEREST

By Professor P. A. BUXTON, F.R.E.S.

(London School of Hygiene and Tropical Medicine.)

IF one wishes to show a large part or the whole of the world's surface on a flat map, there must be great distortion, and it is useless to search for the perfect projection. It is a matter of convenience to find the projection which is best suited to a particular purpose.

For mapping the distribution of terrestrial organisms it seems that Boggs' projection has great value. As the figure shows, the distortion is mainly in the oceans. The projection is recentred for each continental mass, so that the continents are little distorted, except Asia, which has an enormous extent in latitude. The relation of island groups to one another is not much disturbed, except that the east and west Pacific are shown completely separated.

It must be admitted that though this projection is valuable for showing the present distribution of terrestrial plants and animals, it is not suitable for considering the changes in the distribution of land and water (and organisms) which have occurred in past epochs.

Outlines on this projection are obtainable in London from Geographical Publications Ltd., by whose permission the figure is here reproduced.
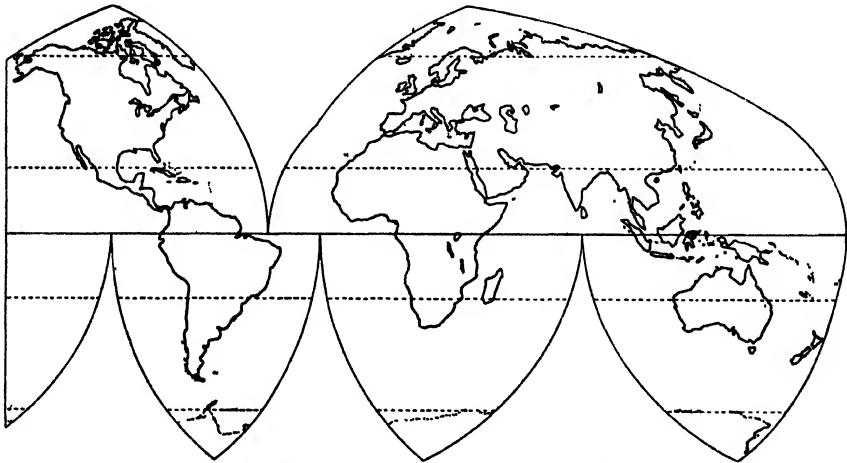

FIG. 1.—Map of the world on Boggs' projection.

METHODS USED IN REARING SMALL INSECTS INFESTING STORED FOOD PRODUCTS

By N. E. HICKIN, Ph.D., F.R.E.S.

IN experiments carried out recently on the food and water requirements of Ptinid beetles, several thousands of these small insects were reared successfully under conditions of controlled humidity and temperature. The methods used are described in this communication, as well as the methods devised for sieving the finely powdered foodstuff for isolation of the live stages—eggs, young larvae, etc.

I wish to thank Dr. O. W. Richards for advice and suggestions.

CULTURE CAGES.

The method of Buxton and Mellanby (1) of using celluloid cylinders was modified by the use of glass cylinders (fig. 1). It was thought that the camphor content in celluloid might be inimical to insects. Sections were cut from wide diameter glass tubing. Diameters of two inches and three inches were found to be practicable. Bolting silk of 90 meshes to the inch was used to cover the ends of the glass cylinders; it was held firmly in position by means of brass clips.
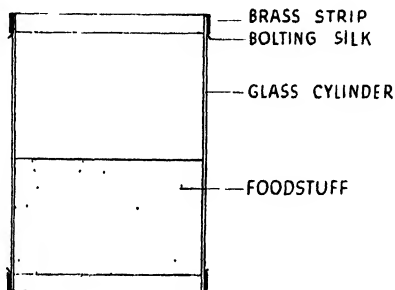

FIG. 1.

Wide diameter glass tubing (2″ and 3″) may be cut easily by the following method : a small cut is made on the glass surface with a sharp file. Strips of blotting-paper, $\frac{1}{2}$″ wide, are then wetted with cold water and wrapped around the tubing, one strip on each side of the cut and about $\frac{1}{4}$″ apart. The tube is then rotated in a large air-gas flame (but not sufficient air to produce a blue cone). After about 20–30 secs. the required length of tubing splits off and now only requires the sharp edges grinding off with emery paper moistened with turpentine.

The brass clips are made by joining $\frac{1}{8}$″ strips of brass foil using a glass cylinder as a former, and fixing the joint with solder. A piece of thin paper under the join insulates the heat (from the operation of soldering) from the glass and also gives the correct diameter for holding the silk on to the glass with a tight fit. A slip of paper giving the identification key (species, foodstuff, humidity, etc.) is wedged between the clip and the silk. The larvae of some species are able to bite their way through bolting silk especially at high humidities, and in this case thin lead foil should be used in place of bolting silk at the lower end of the cage after the foodstuff has attained equilibrium with the desired relative humidity. An alternative method of construction of

culture cages for use with such larvae would be to solder discs of copper gauze (90 meshes to the inch) on to the brass clips. The clips could then be nickel plated in order to prevent possible corrosion of the copper by the damp foodstuffs.

REGULATION OF TEMPERATURE.

The humidity chambers containing the cultures were kept in thermostatically controlled ovens of the standard type. The latter were maintained at 27° C., which is a convenient temperature for experiments of this kind. With foodstuffs in equilibrium with high relative humidities such as 70% and 80%, however, the growth of moulds is very rapid, but if the temperature is fixed at 20° C. the growth of moulds is much less rapid, and, in species with a rapid life-cycle, it may be possible under these conditions to rear a complete life-cycle before the advent of mould formation.
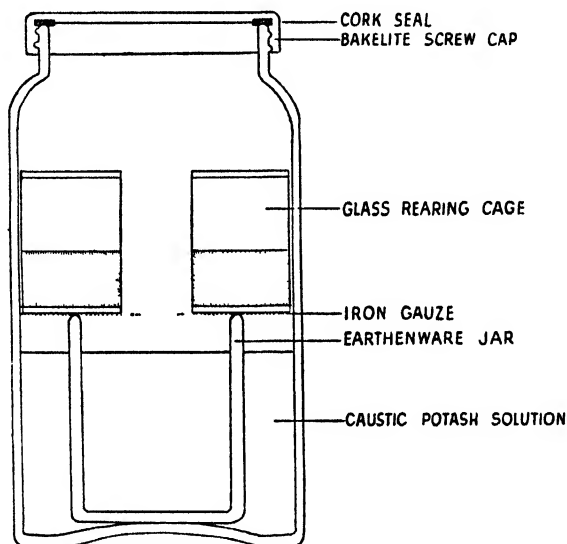

CORK SEAL
BAKELITE SCREW CAP

GLASS REARING CAGE

IRON GAUZE
EARTHENWARE JAR

CAUSTIC POTASH SOLUTION

Fig. 2.

REGULATION OF HUMIDITY.

This was carried out mainly by the method of Buxton and Mellanby (1). "Seven-pound" jars with very little shoulder and bakelite screw stoppers (cork inserts) were used as the humidity chambers (fig. 2). These jars were 6″ in diameter and about 12″ in overall height. The neck was $4\frac{1}{2}$″ in width. One litre of humidity-controlling fluid was poured carefully into the jar and a disc of wide mesh iron or brass gauze was supported on a glass or earthenware cylinder which projected $\frac{3}{4}$″–1″ above the level of the fluid. From four to six culture cages each containing about 50 c.c. of foodstuff (sieved through 60 mesh) were then placed on the gauze shelf. The culture foodstuffs were allowed fourteen days to come into equilibrium with the humidity before infestation. The humidity-controlling fluid for relative humidities between 10% and 90% was caustic potash solution of known strength made up to concentrations given by Buxton and Mellanby (1). Caustic potash solution has the advantage that it does not give off noxious or toxic fumes when particles of foodstuff drop

into it from the culture cages. Also the carbon dioxide from respiration is absorbed.

The caustic potash solutions were changed every twelve weeks, and tests showed that the relative humidities could be kept within 1% of that required. The solution giving 90% relative humidity, however, rapidly carbonated, obviously due to the growth of moulds in the culture foodstuffs. An important point which must be observed in making up caustic potash solutions for humidity control is to check the KOH content of the solid caustic potash. Rapid absorption of carbon dioxide takes place in the air and the caustic potash should be weighed out from material kept in a sealed container and a concentrated solution made up. The KOH content of this solution should then be estimated and diluted accordingly to give the required humidity. Difficulty may be met in making accurate solutions for 10% to 20% relative humidity as the solutions at these concentrations readily solidify on cooling.

Fahmy's (2) experiments showed that *Ptinus tectus* larvae and adults were killed by hermetic sealing, but a cork-glass seal does not constitute a complete air seal. In the experimental method outlined above, a large air space (approximately 1 litre) is left in the jar after the introduction of one litre of the humidity-controlling solution. In addition the humidity chambers were opened each week. Thus sufficient air was always present in the humidity chambers to allow of normal respiration.

METHOD USED FOR ISOLATING LIVE STAGES OF FOOD-INFESTING INSECTS.

A special sieve was constructed in which the infested foodstuff was sifted. The design was such that there was no possible chance of escape of eggs, small
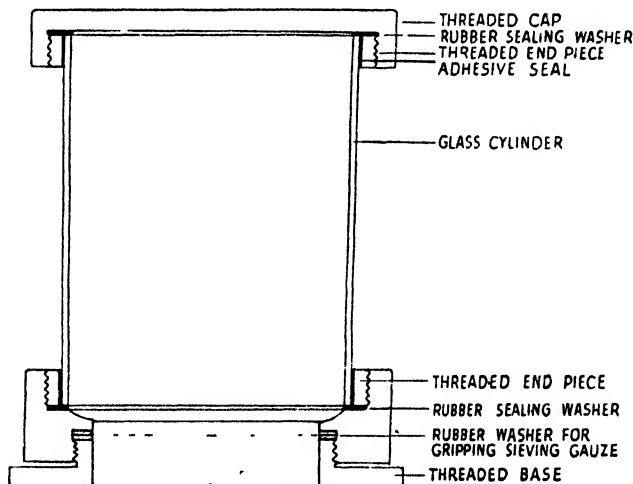

FIG. 3.

larvae, etc., through being "jumped" out of the sieve during the sifting operation. Allowance was made for making a rapid change to a gauze of different mesh. In addition, by unscrewing the body and top of the sieve after a sieving operation, the base, containing the gauze, can be placed directly on to the stage of the microscope for egg counting, etc., thus causing no possible loss due to transference. The cross wires of the sieving gauze also help materially in the counting.

The sieve (fig. 3) consisted of a glass tube 3″ in diameter and 4″ in length. At each end a brass ring was cemented which was threaded on the outside face. A lid, machined out of brass, screwed on to one end of the cylinder. The gauze-holder screwed on to the other end of the cylinder, whilst a base was made to screw into the gauze-holder.

The complete sieve was made to fine dimensions, and in order to hold the gauze and to make satisfactory joints between the glass body of the sieve and the top and gauze-holder, accurately made rubber washers were used. By this means no minute crevices were left in which eggs and small larvae could be hidden. Circles of the sieving gauzes were cut so as to fit into the gauze-holder.
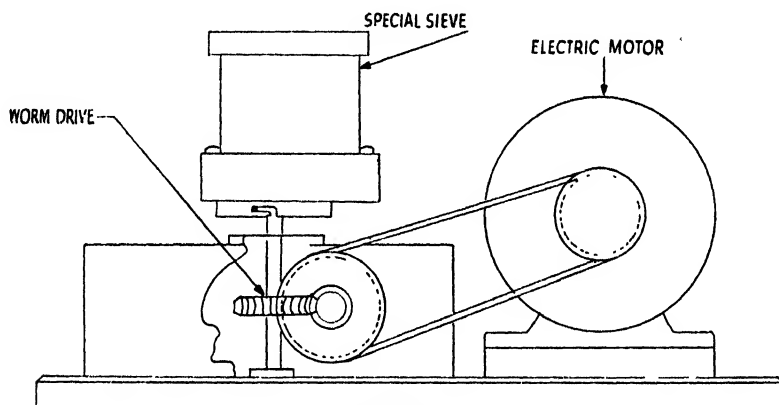

FIG. 4.

A disadvantage of the mechanical sieve proposed by Park (3) is that a vigorous blow is occasioned at the reversal of the stroke so that the material is thrown from one side of the sieve to the other. This is liable to damage the delicate pupae of many insects even though they are protected by cocoons. If, however, the material is subjected to a swirling action, efficient sieving can be brought about without damage to the live stages contained within it. The figure (No. 4) shows the type of mechanical sieving device used to do this. The sieve is mounted with its vertical axis eccentric to a vertical spindle free to rotate. The spindle is driven through a worm-gear by an electric motor. The spindle could, of course, be driven directly. By varying the amount of eccentricity and speed of rotation the conditions for efficient sieving together with non-damage to live stages can be found.

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NOTES ON THE INTERNAL ANATOMY AND IMMATURE STAGES OF *MYCETOPHAGUS QUADRIPUSTULATUS* (LINNAEUS) (COLEOPTERA, MYCETOPHAGIDAE)

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I. INTRODUCTION.

DURING the spring and summer of 1940 many adults and larvae of *Mycetophagus quadripustulatus* (Linnaeus) (1761) were taken at Linton, Cambridgeshire, feeding on many species of fleshy Hymenomycetes (*Pleurotus, Boletus, Polyporus*, etc.). The larva of this common species has been described by Frauenfeld (1867) and Xambeu (1900), but as both of these descriptions are unaccompanied by illustrations and as there exists no good description of the pupa, the opportunity is taken here of illustrating and describing the immature stages.
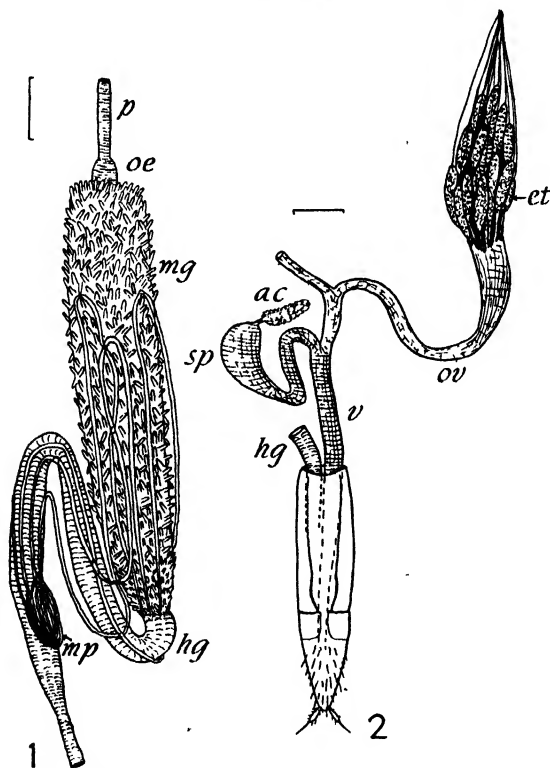
FIGS. 1-2.—*M. quadripustulatus* (L.). (1) Alimentary canal. (2) Female reproductive system. (ac) Accessory gland. (et) Egg tube. (hg) Hind gut. (mg) Mid-gut. (mp) Malpighian tubules. (oe) Oesophagus. (ov) Oviduct. (p) Pharynx. (sp) Spermatheca. (v) Vagina.

The family MYCETOPHAGIDAE consists of about 200 species grouped in some 20 genera of which the great majority, so far as is known, feed on fungi. There exists a diversity of opinion as to the relationships of the family, but to-day

it is usually placed near the COLYDIIDAE. With a view to providing additional characters by means of which the relationships of this family can be better understood, the internal anatomy of the adult and larva has been described.

All illustrations were made by me with the aid of a camera lucida, and lines next to figures correspond to a length of 0·20 mm.

II. INTERNAL ANATOMY OF ADULT.

At the present time there appears to be nothing known of the soft parts of the internal anatomy of adult MYCETOPHAGIDAE. Sharp and Muir (1912) have described the endophallus (internal sac) as a simple tube. Crowson (1938) has described the metendosternite which he says is somewhat similar to that of the COLYDIIDAE.

1. *Alimentary Canal.*

The alimentary canal (fig. 1) has a short stomodaeum which is about one-fourth as long as the mesenteron. The oral part or buccal cavity is not structurally differentiated from the pharynx. The pharynx is a narrow tube which has its posterior end slightly broadened to form an oesophagus. There is no crop or ingluvies and the posterior part of the oesophagus is feebly invaginated into the mesenteron to form the cardiac valve. There are no caeca on the anterior margin of the mid-gut, and the external surface of the whole of the mid-gut is closely covered with prominent regenerative crypts which are about 0·08 mm. long anteriorly, while near the posterior end they are slightly shorter.

The hind gut is about a third longer than the mid-gut and has a single long loop in the region of the abdomen. At the anterior end of the hind gut six Malpighian tubules arise at more or less even intervals around the gut. These tubules extend forwards for a varying distance—often as far as the prothorax—and then turn posteriorly. At about the middle of the hind gut they lie very close to the walls of the gut and at about apical fourth, on inner side of loop, the six tubes form a large, closely coiled mass. Over this terminal coiled mass is a thin membrane which also appears to hold the Malpighian tubules against the gut for a short distance anterior to the coiled mass. This membrane is probably homologous to that described in *Niptus hololeucus* (Fald.) by Marcus (1930) or in *Tenebrio molitor* L. by Poll (1932). Wigglesworth (1939) calls this structure the perinephric membrane. The Malpighian tubules are pale brown except near their point of origin where they are white, but in a few specimens examined the tubules were everywhere white. The walls of the gut adjacent to the coiled mass appear to be thinner than elsewhere, as is the case in other cryptonephric Coleoptera with a similar arrangement of the tubules. Wigglesworth (1939) and others have suggested that this section of the Malpighian tubules almost certainly takes up water reabsorbed from the rectum, an idea which they claim is supported by the fact that cryptonephridism does not occur in the aquatic beetles. But probably more than half of the aquatic beetles belong to the suborder Adephaga, a suborder which in any case has no known cryptonephric terrestrial species. It has recently been shown by Hinton (1939) that among the Polyphaga there is one family (DRYOPIDAE) of the most truly aquatic of all beetles where cryptonephridism is the rule. Among the LIMNICHIDAE the most aquatic genus (*Lutrochus* Er.) is cryptonephric, while all of the three terrestrial genera (*Ersachus* Er., *Byrrhinus* Mots., and *Limnichites* Casey) that have been examined have the Malpighian tubules ending freely in the body cavity.

2. *Central Nervous System.*

The central nervous system has three discrete thoracic ganglia. The first abdominal ganglion is fused to the third thoracic, the second, third, and fourth are discrete, the fifth is contiguous to the sixth, and the sixth is contiguous to the fused seventh and eighth.

3. *Reproductive System.*

The male reproductive system is as shown in fig 3. The ejaculatory duct is a long, well-muscled tube which is variously coiled when retracted into the
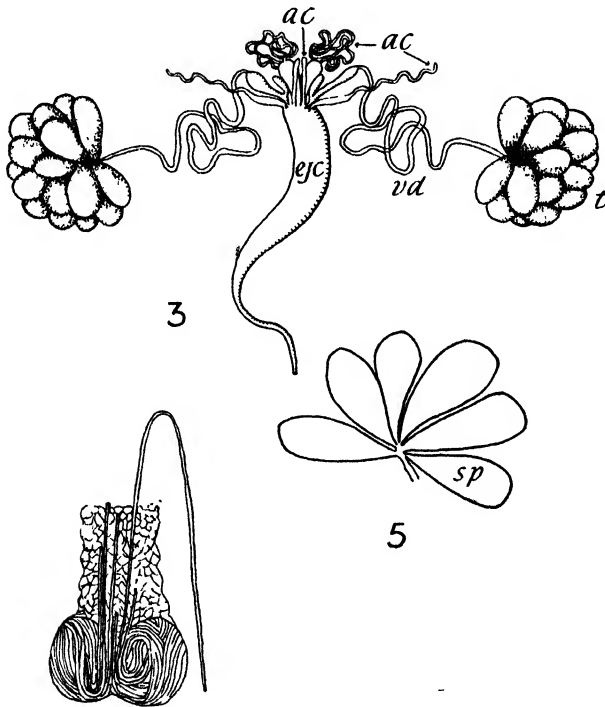
Figs. 3–5.—*M. quadripustulatus* (L.). (3) Male reproductive system. (4) Semi-diagrammatic view of cap of Malpighian tubules of larva. (5) Diagrammatic view of some sperm tubes. (ac) Accessory glands. (ejc) Ejaculatory duct. (sp) Sperm tube. (t) Testis. (vd) Vas deferens. .

body. There are three types of accessory glands as shown in fig. 3. Each testis usually has 15 sperm tubes. One specimen examined had 18 sperm tubes to each testis, while one had 16 on one side and 20 on the other. The sperm tubes are sessile, *i.e.* they open directly into the vas deferens and there is no distinct vas efferens (fig. 5). The tubes are not collectively enclosed in a membranous sheath. In sexually mature specimens the vasa deferentia become enormously swollen and serve as vesiculae seminales, and when this

is the case the pouches near their point of entry into the ejaculatory duct are no longer evident. In sexually mature specimens the testes and vasa deferentia form a large mass occupying much of the body cavity above the last four abdominal sternites. The testes and vasa deferentia lie ventro-lateral to the gut.

The female reproductive system (fig. 2) has 17 acrotrophic egg tubes to each ovary. The accessory gland (ac) is connected by a short duct to the spermatheca (sp) which opens into the apex of the vagina. The apex of the vagina appears to serve as the bursa copulatrix, there being in this species no distinct and specialised part of the vagina, *e.g.* a diverticulum, which serves as a bursa copulatrix.

III. Description of Pupa.

Two larvae taken under the bark of a rotten stump which had grown a few crops of a large *Polyporus* were placed in a jar with a piece of the fungus. Both made oval, nearly round cells in the debris under the fungus, and the cells could be seen by looking through the bottom of the jar. These cells were found completed on 9.viii.1940, and by the morning of the 13th both larvae had pupated. One of these was preserved in Pampel's fluid for description, and the other was allowed to emerge, which it did on the 20th—seven days after pupation. The length of the pupal period probably varies very greatly according to local conditions of temperature and humidity. My pupa was kept in a moist jar in a warm room. Xambeu (1900) gives 12 to 15 days as the length of the pupal period and Frauenfeld (1867) 16 to 20 days.

During the first few days the pupa was lying on its back, but on the fifth day it was found on its ventral side and just before emergence it was found on its side. Pupae have been found in the rotten wood and other debris under the bark of a tree stump. Dr. K. G. Blair has found the pupa actually in a large *Polyporus*, and Perris (1877 : 88) says he found a large number of larvae and pupae in *Boletus imbricatus* and larvae and pupae of a related species, *M. multipunctatus* Fabricius (1792), in *Boletus suberosus*.

When the adult first emerges it is a uniform testaceous colour. One which emerged on the morning of the 26th was entirely testaceous but by 11.30 p.m. the cuticle had darkened so that the two basal spots were quite distinct. By the 28th this specimen was fully coloured.

Female pupa : Length, 5·5–6·0 mm.; breadth (greatest breadth is across base of prothorax if wings are not included), 2·1 mm. Body oblong; cuticle white with reddish eyes and apical part of projections of ninth abdominal segment brownish. *Head* completely concealed from above by pronotum; surface with ten long setae on each side (fig. 7) as follows : two on clypeus; one opposite base of antenna; two in a line just above inner margin of eye; two more or less opposite these and nearer middle of head; one on extreme dorsal margin opposite inner margin of eye; and two on margin of gena, one opposite middle of eye and the other opposite posterior third of eye. Antennae extend posteriorly and slightly outwards to a point opposite anterior region of metasternum; surface with acute tubercles arranged as shown in fig. 6. Maxilla with a single long spine on outer side near base of last segment. *Pronotum* with shape and 40 setae as shown in fig. 6; on anterior fifth with a narrow, feebly impressed, median longitudinal line. Mesonotum with a single long seta on each side at posterior two-fifths near base of elytra; elytra extending posteriorly and slightly outwards to a point opposite posterior margin of third abdominal tergite; elytra without setae or tubercles. Metanotum on each side with a single long seta on posterior two-fifths; wing extending posteriorly and slightly outwards

to a point opposite middle of fourth abdominal tergite. Abdominal tergites one to eight with shape and setae as shown in fig. 6; each tergite with four long setae on each side, two lateral and two on about lateral third of segment near posterior margin; ninth tergite with each posterior angle produced into a long, stout spine which is dark brown and heavily sclerotised at apex (fig. 6) and each side of this segment with five long lateral or ventro-lateral setae. *Beneath* without setae on pro-, meso-, and metasternites. Abdominal sternites one to four transverse and with posterior and anterior margins more or less straight;
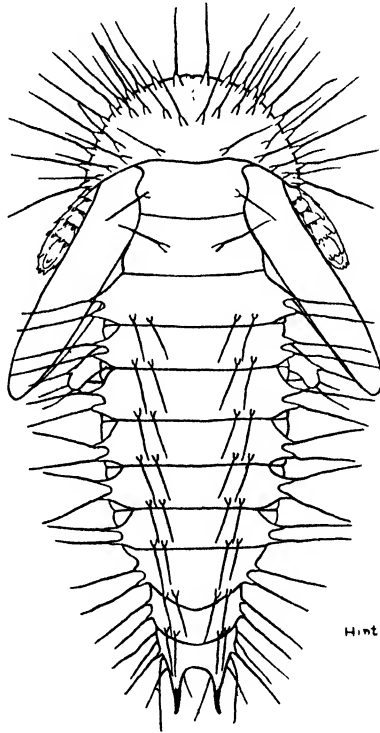

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FIG. 6.—*M. quadripustulatus* (L.). Dorsal view of pupa.

one without setae; two to four with a single long seta on each side on posterior third or fourth of lateral fifth or sixth of sternite; five and six with posterior margin broadly arcuate and with setae as shown in fig. 8; seven without setae and with posterior part lobed (fig. 8) and each lobe enclosing one of the coxites of the female genitalia. *Legs* with front pair extending to middle of metasternite and tarsi separated by a distance equal to length of fifth segment. Second pair extending to middle of second abdominal sternite and with last three segments contiguous. Hind pair extending to posterior third of fourth abdominal sternite and with most of tarsi contiguous. Each leg with three long setae forming an oblique row on ventral apical part of femora. *Spiracles* of abdomen placed on sides and opening at level of cuticle, not on small tubercles.

Male : No male pupae were available, but when found they will be easily distinguished from the female by the three instead of four segmented tarsi of the front legs.

Comparative notes : The pupa of both *M. piceus* Fabricius and *M. fulvicollis* Fabricius has been described, the first by Perris (1877) and the second by Saalas (1923). The following key will serve to distinguish all known pupae of *Mycetophagus.*

1. Meso- and metanotum with two setae on each side   .   *M. piceus* Fabricius (1792).
-. Meso- and metanotum with only one seta on each side . . . .   2.
2. First eight abdominal tergites with one seta on each side at about lateral
   third of segment near posterior margin.   Ninth tergite with seven or eight
   setae on each side   .   .   .   .   .   *M. fulvicollis* Fabricius (1792).
-. First eight abdominal tergites with two setae on each side at about lateral
   fourth or third of segment near posterior margin.   Ninth tergite with
   five setae on each side   .   .   .   .   *M. quadripustulatus* (Linnaeus) (1788).
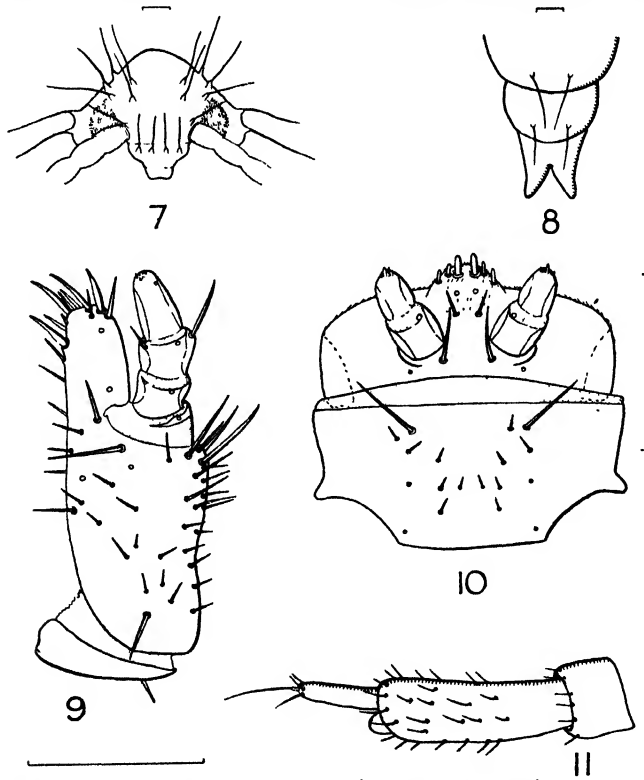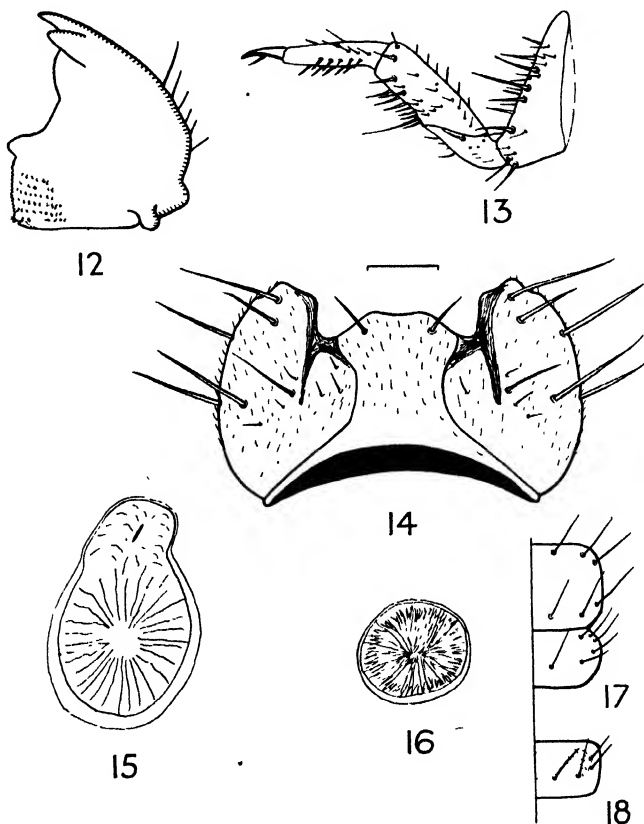

Figs. 7–11.—*M. quadripustulatus* (L.).   (7) Front view of head of pupa.   (8) Ventral view
of last three abdominal sternites of pupa.   (9) Ventral view of left maxilla of larva.
(10) Ventral view of labium of same.   (11) Lateral view of antenna of same.

IV. DESCRIPTION OF LARVA.

Mature larva (figs. 4, 9–19): Length, 8·5 mm.; breadth (across broadest point, which is near apex of metathorax), 1·0 mm.   Elongate, subparallel, and more or less elliptical in cross section; dorsal surface evenly convex.   Cuticle testaceous and with moderately dark brown areas as follows : head; anterior four-fifths of protergum and eighth abdominal tergite; anterior two-thirds of meso- and metatergum and sixth and seventh abdominal tergites; anterior half or slightly more of abdominal tergites one to five inclusive; and

apical projection of ninth segment. *Head* slightly broader than long (1·04 mm. : 0·95 mm.); coronal suture short (0·05 mm.); frontal sutures diverging forwards in an irregularly curved line to a point opposite ocelli and then making a right angle turn to continue in a more or less straight line to anterior margin of head near outer side of antennal bases. Cuticle moderately sparsely clothed with suberect to erect, fine, short hairs and with five long, erect setae on each side as follows : one near anterior margin near apical angle; one opposite and lateral to point where frontal suture makes a right angle, turn; and three forming a slightly oblique line on each side on basal third of head; ventral surface

FIGS. 12–18.—*M. quadripustulatus* (L.) larva. (12) Ventral view of left mandible. (13) Posterior face of left front leg. (14) Ventral view of head. (15) Mesothoracic spiracle. (16) Spiracle of fourth abdominal segment. (17) Diagram of long setae of pro- and mesotergum. (18) Same of first abdominal tergite.

of head with setae as shown in fig. 14 (fine setae are only approximate); cuticle between setae moderately sparsely and usually transversely alutaceous. Five ocelli arranged on each side as follows : three in a transverse row opposite base of antenna; fourth smaller and posterior and slightly dorsal to first of row; and fifth just behind second of row. Antenna (fig. 11) as figured. Clypeus slightly longer than first segment of antenna; anterior margin truncate and angle on each side broadly rounded. Labrum with anterior margin broadly rounded and with about 10 moderately long setae; each side rounded and with five very long setae; labrum on each side at about anterior third with two very

long setae and elsewhere on surface with numerous much finer and shorter setae. Mandible (fig. 12) without a prostheca; each with two apical acute teeth and only right mandible with a short sub-apical third tooth; mola moderately depressed and with grinding surface facing buccal cavity [1] and also extending laterally over part of ventral side (fig. 12). Maxilla (fig. 9) with palp 3-segmented and galea and lacina completely fused; setae as figured. Labium (fig. 10) with palp 2-segmented; setae as figured. *Tergites* with numerous fine, short setae and also with a few very long erect setae. Protergum with six long, erect setae on each side as shown in fig. 17. Meso- and metatergum with six long, erect setae
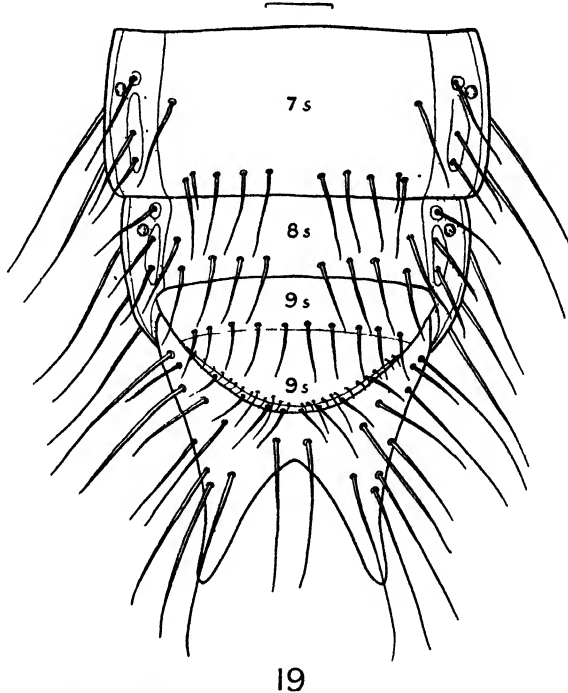

FIG. 19.—*M. quadripustulatus* (L.).   Ventral view of end of abdomen of larva.

on each side as shown for mesotergum (fig. 17). Abdominal tergites one to eight with four long setae on each side placed as shown in fig. 18. Ninth tergite with two long dorsal setae on each side near base of apical projection, the other setae seen from dorsal view being ventro-lateral or ventral and are shown in fig. 19. *Sternites* and *pleura* of abdominal segments one to six more or less like those figured for segments seven and eight (fig. 19). Ninth sternum (fig. 19) as figured. *Legs* with front pair shortest and hind pair longest; posterior legs setose like front legs (fig. 13). *Spiracles* opening at level of cuticle in ventro-lateral pleural membrane on anterior third or half of segment; mesothoracic spiracle as figured (fig. 15); spiracles of first eight abdominal segments similar to that of fourth segment (fig. 16).

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[1] Böving and Craighead (1931) say that the larvae of the MYCETOPHAGIDAE can be distinguished from those of the OEDEMERIDAE, CEPHALOIDAE, ZOPHERIDAE, SYNCHROIDAE, and PEDILIDAE by having the mola of the mandible depressed and the grinding surface on the ventral or on both ventral and dorsal sides, whereas in the OEDEMERIDAE, etc. the mola is not depressed and the grinding surface is facing the buccal cavity. I have examined the mandibles of *Typhaea stercorea* (Linnaeus) (1758) and find that they are similar to those of *M. quadripustulatus* in all important respects.

A number of larvae belonging to earlier instars has been examined, but the arrangement of the long setae in these is apparently the same as in the mature larva.

V. Internal Anatomy of Larva.

The larvae of a number of species of MYCETOPHAGIDAE have been described, but the structures of the internal anatomy have been entirely neglected. Here the alimentary canal and the central nervous system of the larva is compared with that of the adult.
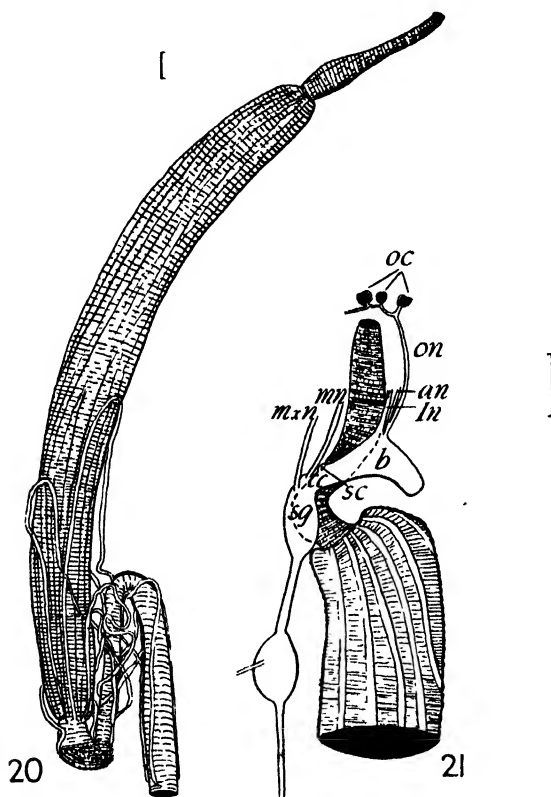
FIGS. 20–21.—*M. quadripustulatus* (L.) larva. (20) Alimentary canal. (21) Lateral view of brain, suboesophageal ganglion, and first thoracic ganglion. (an) Antennal nerve. (b) Brain. (cc) Circumoesophageal connective. (ln) Labrofrontal nerve. (mn) Mandibular nerve. (mxn) Maxillary nerve. (oc) Ocelli. (on) Optic nerve. (sc) Substomodaeal commissure. (sg) Suboesophageal ganglion.

1. *Alimentary Canal.*

The gut (fig. 20) has a very short stomodaeum which is only about a fifth as long as the mesenteron, whereas in the adult it is about a fourth as long. The oral part of the stomodaeum or buccal cavity is not structurally differentiated from the pharynx. The pharynx is a narrow tube which has its posterior end slightly broadened to form the region known as the oesophagus. There is no distinct crop or ingluvies, and the posterior part of the oesophagus is feebly invaginated into the mesenteron to form the cardiac valve. In some specimens

examined the gut was more or less full of food and there was no constriction between the stomodaeum and mesenteron, but in these cases the two structures could be distinguished by the arrangement of the muscles. The stomodaeum has the longitudinal muscles of the wall inside the circular muscles, whereas this arrangement is reversed in the mesenteron.

The mesenteron is a simple more or less parallel tube without caeca and without projecting regenerative crypts, as is the case in the adult. It is relatively much longer in the larva than in the adult.

The proctodaeum is slightly more than half as long as the mesenteron and has a single loop which extends as far anteriorly as the sixth abdominal segment. In the adult the proctodaeum is a third longer than the mid-gut. There are six Malpighian tubules which have their origin at the anterior end of the hind gut and arise at equal intervals round the gut. These tubules extend forwards for a varying distance before returning to the hind gut where they are variously coiled and looped and then come together to form a coiled cap (figs. 4 and 20) which covers the first bend of the hind gut. From this cap they extend closely applied to the walls of the hind gut to a point near the anus where they end blindly. Both the cap and the tubules caudal to the cap are covered by a thin " perinephric " membrane (fig. 4) similar to that already described for the adult. As has already been pointed out, in the adult the Malpighian tubules end in the coiled mass and do not extend along the walls caudal to this mass. In some specimens examined the Malpighian tubules were pale brown except near their point of origin and posterior to the coiled cap where they were white, while in other specimens they were white everywhere.

2. *Central Nervous System.*

The brain is as shown in fig. 21. The ventral chain has three thoracic and eight abdominal discrete ganglia. The larva has a greater number of discrete abdominal ganglia than the adult, and this appears to be the general rule among the Coleoptera and probably also among most other orders of insects.

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THE TERMINOLOGY USED BY JACOB HÜBNER

By Francis J. Griffin and Joséphine Griffin-Gillen.

Some years ago it became known to the senior author that there then existed in Germany the surviving manuscripts of Jacob Hübner apparently complete as they were left at his death. By a succession of fortunate circumstances they had survived the intervening century and were still unhurt, in fact until the war of 1914–1918 even the copper plates of the Hübner works were in existence and were only destroyed when commandeered by the German Government for use in war purposes. At that time the manuscripts were wrapped in several large bundles and stored in a dark corner in a Berlin warehouse and, fortunately, overlooked. The story of the survival of the documents is worth recording. On the death of Hübner his work was continued by Carl Geyer, who obtained charge of all unpublished material and the stock of the published works. Geyer continued the publication of the illustrations to the works and issued a very small amount of text, probably that part in an advanced state of preparation, but obviously he paid little attention to the great mass of it which required long study and much preparation to bring it to a state ready for publication. On the death of Geyer the whole collection passed to Herrich-Schäffer, who utilised certain of its contents but published no text, as such, to Hübner's works, although he regarded his own work as a continuation of, or possibly a replacement of, Hübner's. On the death of Herrich-Schäffer the whole of the remains, still obviously relatively complete, was acquired by the firm from whom the Society obtained possession with the assistance of one of its Fellows, Mr. R. W. Lloyd. The collection was secured as a result of a visit made to Germany by the senior author, who was able to agree to terms and to transport the very bulky parcels to London. The original patterns of the coloured plates of Hübner's works, and of Geyer's continuations, were obtained by the same means at a later date and now form a valued part of the National Collection in the British Museum (Natural History), where they are available for study by interested persons.

The collection of manuscripts, almost entirely in Hübner's own handwriting, was extremely extensive—it weighed some hundredweights—and has so far not been worked out thoroughly although we studied some part for Mr. Francis Hemming when he was preparing his work *Hübner* published by the Society in two volumes in 1937. That part was, however, restricted to such information as was concerned with, or threw light on, the dates of publication of the several works of Hübner and the Geyer continuations, and, in the nature of the subject, took little account of the great mass of unpublished material which was obviously intended by Hübner to form the basis for the text to his works. Our study of part of the manuscripts gave us a foretaste of their interesting contents and so attracted us to this strange author that we have from time to time made further efforts to study them. So far this examination is still not exhaustive and we can see no immediate likelihood of its becoming so in the near future. It has seemed better, therefore, to proceed piecemeal and endeavour to complete our results part by part, each in some measure complete in itself, yet forming an integral part of the whole.

As a necessary prelude to such a study it is an obvious necessity to define the very unusual terms used by Hübner in his writings. It is evident to us that Hübner was a very determined man who held strongly the view that the tongue which he spoke and in which he wrote was to be a really pure " German " with no foreign influences; a doctrine not unfamiliar to our contemporaries to-day. It appears, however, equally apparent that he was of a shy, retiring, disposition and that he kept himself very much to himself. He was not a man of wealth and indeed was on occasions not unacquainted with the feeling of poverty. By a fortunate chance he was a meticulously careful man who made copious notes and these he kept carefully. Perhaps not so fortunately he was constantly revising his ideas and re-writing what he had already committed to paper. This is, we believe, the true reason for his not publishing a satisfactory text to his works. It is a habit not unknown to his countrymen and has been the cause of much labour to us, since it frequently took the form, with Hübner, of correcting, re-correcting, and again correcting, a manuscript with the result that it is now possible to decipher the writing only with extreme difficulty. Happily Hübner has left lists of some of the terms he used and one such has already been published in his *Lepidopterologische Zuträge*, 1820, of which a facsimile has been issued in Hemming's *Hübner* 1937, and by Griffin in *J. Soc. Bibl. nat. Hist.* 1 : 159–192, 1938. A second list has now come to light in the unpublished manuscripts in the Library of the Royal Entomological Society of London, and it is this which we now reproduce. The two lists are complementary and not duplicates, although of the 145 terms in our list 73 are common to both but, in some cases, with relatively unimportant variations.

In our list, which is in two parts, we have included in parenthesis [ ] those terms which are struck out in the manuscript by Hübner. The lists are on two sides of a leaf of paper and are written by Hübner, the first being the German list with the Latin equivalents and the second the Latin terms with the German equivalents. To this we have added, with the assistance of Dr. F. E. Zeuner, the modern terminology. In this connection we have utilised the list published by Hübner in 1820. It is a pleasure to record our thanks to Dr. Zeuner.

We have endeavoured to copy faithfully the words listed below and it should be assumed that any apparent errors in the German or the Latin as given above are copied from the original.

Körperliche Terminologie von der Schmettlinge Flieggestalten.

German	Latin	Modern
After	Anus	Anus
[Afterklappe	Valvula]	?supra-anal plate
[Afterdecke	Tegmen]	supra-anal plate
[Afterglied	Anium]	anal segment
Achsel	Axilla	shoulder
Anfang	Orsus	beginning
Arm	Armus	fore-leg
Arsch	Clonus	anus
Auge	Oculus	eye
[Bürzel	Culula]	the 2 abdominal segments next to the anal segment
vorderes	anteriora	
hinteres	posteriora	
Backen	Mala	" the sides of the head below the eyes," genae
Balg	Follis	pelt, skin
Bart	Barba	beard
Bärtgen	Barbula	small beard
Bauch	Venter	underside of abdomen

Borste	Seta	seta
Brust	Pectus	underside of thorax
Bürste	Scopa	tufts on first 6 abdominal segments
Bürzel	Culus	the 2 abdominal segments next to the anal segment
[Bürzelglied	Culula]	
Buge	Flexus	underside of tarsus
Decke	Tegmen	supra-anal plate
Deckgen	Tegilla	patagium
Dorne	Spina	
Dörngen	Spinula	spines on spur of leg
Ende	Extremum	end
[Ferse	Talus]	
Finger	Digitus	tarsal segment
Fläche	Pagina	upper and lower, surface of wing
obere	subjecta	
untere	dejecta	
Flügel	Ala	wing
Füge	[Junctura] *	articulation
Fuss	Pes	hind leg
Gegende	Tractus	area, region
Glied	Artus	mouthparts, palpi, eyes, antennae, legs, wings and abdominal appendage
Gliedgen	Articulus	segments of antennae, palpi and legs
Haar	Pilus	hair
Hand	Manus	tarsus
Halfter	Capistrum	halter
Hals	Collum	intersegmental skin connecting head and thorax
[Halsglied	Jugulum]	
Haut	Corium	integument
[Haber	Sypho]	?proboscis
Häutgen	Coriolum	?small, thin area of skin
Henkelgen	Ansula	frenulum—hook on fore-wing
Herzglied	Cardium	mesothorax
Höhle	Specus	cavity
Hüfte	Coxa	coxa of middle or hind leg
Hülle	Amictus	covering of scales and hairs
Joch	Jugum	prothorax
Kamm	Crista	crest, comb
Kegelgen	Conulus	basal segment of antenna
Kehle	[Gulae] Striatura	" part of the head below the mouth "
Kinn	Mentum	chin
Kläugen	Unguiculus	tarsal claw
Klammer	Fibula	clasp
Kläppe	Valva	" Two parts of the anal segment embracing the anus "
Klaue	Ungulus	tarsal claws
[Klufte] Knie	Genu	knee
Knospe	Gemma	" bud-like growth," a small prominence above the nostrils
Kopf	Caput	head
Krage	Collare	patagium
Kröpel	Cartilago	cartilage
Küppel	Copula	frenulum
Langer	Ulna	tibia
Läppgen	Lobulus	small lobe
Lappe	Lobus	lobe

Added from the Latin list.

Leib	Corpus	body
Leite	[blank]	
Lende	Lumbus	
Lendglied	Lumbulus	
[Lenden]	[blank]	
Lenkung	Commissura	articulation of wings
Lippe	Labium	" middle segment of palpus "
Locke	Antia	" hair tufts at base of antennae "
Mäne	Juba	mane
Mitte	Medium	middle
Mündung	Orificum	margin of the mouth " mostly extended into a proboscis "
Mund	Os	mouth
Nase	Nasus	nose
[Polstergen	Cenchri]	prominences of the metathorax
Nacke	Cervix	occiput
Ohr	Auris	antenna
Panze	Thorassa	integument
Pfeifgen	[blank]	pulvilli
Pölstergen	Culcitrula	" prominence of the metathorax "
Rand	Margo	margin
Raum	Spatium	area between veins
Reger	Agini	" posterior segment of palpus "
Reistgen	Fasciculus	tuft of hair
Richtung	[blank]	
Rinne	Carina	?furrow, sulcus
Röhrgen	Fistula	a small pipe
Rücke	Dorsum	back of thorax
Rüssel	Proboscis	proboscis
Rüste	Tarsus	tarsus
Rumpf	Truncus	thorax
Sauger	Licitrix	
Saum	Fimbr	fringe
Scheitel	Vertex	vertex
Schiene	Tibia	tibia
Schildgen	Clypeolus	small shield
Schiengen	Tibiola	
Schloss	Anium	anal segment
Schnaube	Naris	nostril
Schnäuzgen	Rostella	" anterior segments of palpus "
Schneide	Acies	edge
Schöpfgen	Cirrulus	tuft
Schopf	Cirrus	tuft of erect hairs or scales on back of thorax
Schraube	Limes	
Schüppgen	Squammula	wing scale
Schultern	Humeri	?coxa of fore-leg
Schuppe	Squama	wing scale
Schwanzglied	Codum : 11tes Gl.	" eleventh segment "
Schweifgen	Codicula	small tail
Schwiele	Tomentum	pod
Schwinge	Jacta	fore-wing
Seite	Latera	side of thorax below the wings
Sene	Nervus	wing-vein
Senke	Vergens	hind wing
Sinnling	Sensorium	?sense organ
Sohle	Planta	sole
Speiche	Radius	?main vein

Steiss	Tergum	?back of last abdominal segment
Stirne	Frons	frons
Streichler	Palpus	palpus
Strotzling	Turgium	4 middle segments of abdomen between the "weichen" and "Bürzeln"
Stütze	Fulcrum	leg
Theil	Membrum	?segment
Theilung	Partitio	?partition, division
Träger	Gestor	middle leg
Waste	Armum	
Wange	Gena	eye-socket
Wanst	Abdomen	abdomen
Wehre	Lacerta	femur
Weiche	Ile	2 first segments of abdomen
Weichglied	Lumbium	metathorax
Wischergen	Penicilla	pencil of hairs
Wolle	Lana	wool
Zeugling	[blank]	?genital organ

Abdomen	Wanst		Culula	Burzelglied
Acies	Schneideapfel		Culus	Burzel
Acula	Kerbe			
Agina	Reger		Digitus	Finger
Ala	Flügel		Dorsum	Rucke
Alvus	Leib			
Amictus	Hülle		Exitus	[blank]
Anium	Afterling		Extremum	Ende
Ansula	Henkelgen			
Antia	Locke		Fasciculus	Reistgen
Anus	After		Fibiae	[blank]
Arm	Waste		Fistula	[Röhrgen] Pfeifgen
Armus	Arm		Flocca	Locke
Articulus	Gliedgen		Folles	Balg
Artus	Glied		Frons	Stirn
Auris	Ohr		Fulcrum	Stütze
Barba	Bart		Gemma	Knospe
Barbula	Bärtgen		Gena	Wange
[Basis]	[blank]		Gestor	Träger
			⌊Gula	Kehle]
[Capistrum	Halfter]			
Caput	Kopf		Humerus	Schulter
Carina	Rinne			
Cauda	Schwanz		Jacta	Schwinge
[Cenchr]	[blank]		Ile	Weiche
Cirrulus	Schöpfgen		Ilius	Weichling
Cirrus	Schopf		Juba	Mäne
Clonus	Arsch		Jugulum	Halsling
Clypeolus	Schildgen		Junctura	Fuge
Codicula	Schwänzgen			
Collare	Halskrage		Labium	Lippe
Collum	Hals		Labrum	[illegible]
Commissura	Lenkung		Lacerta	Wehre
Conulus	Kegelgen		Lana	Wolle
Cordium	Herzglied		[Latebra	Höhle, Winkel]
Corium	Haut		Latus	Seit
Corpus	Leib		Licitrix	Sauger
Coxa	Hüft		Limes	Schraube
Culcitrula	Polstergen		Lobulus	Läppgen

Lobus	Lappe	Seta	Borste
Lumbulus	Lendling	Spatium	Raum
Lumbus	Lende	Specus	Höhle
		Spina	Dorn
Manus	Hand	Spinula	Dörngen
Margo	Rand	Squamma	Schuppe
Medium	Mitte	Squammula	Schüppgen
[Mentum]	[blank]	Striatura	Kehle
Naris	Schnaube	[Talus	Ferse]
Nasus	Nase	Tarsus	Rüste
Nervus	Sene	Tegilla	Deckgen
		Tegmen	Decke
Oculus	Auge	Tergum	Steiss
Orificum	Mundung	Thorassa	Panze
Orsus	Anfang	Tibia	Schiene
Os	Mund	Tibiola	Schiengen
		Tomentum	Schwiele
Pagina	Fläche	Tractus	Gegend
Palpus	Streichler	Truncus	Rumpf
Paries	[blank]	Turgium	Strotzglied
Pectus	Brust		
Penicilla	Wischgen	Valva	Klappe
Pes	Fuss	Valvula	Kläppgen
Pilus	Haar	Venter	Bauch
Planta	Sohle	Vergentes	Senken
Proboscis	Rüssel	Vertex	Scheitel
Rostella	Schnauze	Unguiculus	Kläugen
		Ungulus	Klaue
Sensorium	Sinnling		

BOOK NOTICE.

' *Essays in Philosophical Biology.* By W. M. WHEELER. Selected by Professor G. H. PARKER. 8vo. Cambridge (Harvard University Press), 1939. Price 16*s.* 6*d.* pp. xv + 261, 3 pls., 6 figs.

This volume contains twelve essays which have already been published but have been selected by Prof. Parker partly because most of them are now out of print and partly because they " are utterly unique in the history of American Biology."

The essays here presented are : the ant-colony as an organism; Jean-Henri Fabre; on Instincts; the Termitodoxenia, or biology and Society; the organization of research; the dry-rot of our academic biology; emergent evolution and the development of Societies; Carl Akeley's early work and environment; present tendencies in biological theory; hopes in the biological sciences; some attractions of the field study of ants; animal societies.

The volume is prefaced by a short foreword and the appreciation of Wheeler originally published in *Science* in 1937.

Several of the essays were originally published in periodicals not normally available to entomologists and their appearance in this volume will bring them before the wider public.

The book is published in England by Sir Humphrey Milford (Oxford University Press).

PROTHETELY IN A LARVA OF *SMERINTHUS* HYBR. *HYBRIDUS* STEPHENS (LEPIDOPTERA)

By E. A. COCKAYNE, D.M., F.R.C.P., F.R.E.S.

PROTHETELY is a rare phenomenon in the Lepidoptera and none of the examples recorded is exactly like the one described in this paper. The earliest record of this abnormality is a larva of *Bombyx mori* L. described by Majoli in 1813. After the fourth ecdysis it had a small head with black faceted eyes placed close together and grey antennae. The thorax was narrow and the third somite was like that of a larva : there were two pairs of wings, grey in colour, the first pair long and narrow and the second pair shorter and still narrower. The abdomen was like that of a larva in form and number of somites. Very similar to this is a larva of *Melanippe montanata* described by Jones. It was one of twelve, which grew much faster than the rest, and in its last instar had pectinated antennae and imaginal legs. Harrison records a larva of the hybrid *Oporinia dilutata* Schiff. ♂ × *O. autumnata* Borkh. ♀. It was one of fourteen, which in the penultimate instar instead of moulting normally spun silken pads and remained motionless for a fortnight. Thirteen died owing to interference by other larvae caged with them, but the remaining one, which had been isolated, moulted after five weeks and then showed imaginal characters. It had a very small head, antennae with many segments, and eyes with both imaginal and larval characters. There were four rudimentary wings with vestiges of imaginal neuration, one 3 mm. long and three 1·75 mm. long. The legs approximated to those of an imago in structure. Kolbe gives a description and figures of a larva of *Dendrolimus pini* L. sent to him by Winneguth. It had long chitinised antennae with seven segments, large and abnormal maxillae, and legs, which were large and heavily chitinised. There were five other larvae with the same abnormality. They were reared from inbred stock. The first generation hatched in January 1902 and produced imagines in May. From a pairing of two of these a second generation was produced in June consisting of the six abnormal larvae. The imaginal characters were noticed after they had gone through three moults. The larva sent to Kolbe produced a small male moth.

On 11 June, 1940, Mr. H. B. Williams sent me three larvae of *Smerinthus* hybr. *hybridus* Stephens (*Smerinthus ocellatus* L. ♂ × *Laothoë* (*Amorpha*) *populi* L. ♀). Two were full-grown, but the third was in the penultimate instar. It fed on sallow and changed skin into the last instar on 24 July. Mr. Williams told me that it had grown much more slowly than the rest of the brood, most of which had pupated before 8 July. It appeared to be normal until the last instar, when it was seen to have developed a number of imaginal characters. As it was unable to eat I killed and preserved it on 25 July.

The antennae of the normal larva are very short and consist of three, or, according to some authors, four segments, all of which are green. In this abnormal larva the antennae are about 6 mm. long, the right consisting of seven and the left of six segments. The basal segment is broad, rounded, and green, the second is short and narrow, nearly spherical in shape, dark brown, and shining. The third is longer and much broader with two or three irregular grooves running across its surface. It is smooth, shining, and dark brown in colour. The fourth segment of the right antenna is much longer, dark brown with a polished surface crossed by transverse grooves on the anterior aspect. The fifth is somewhat distorted, tapering very much distally, dark brown in colour, with deep transverse

grooves running round its circumference. The fourth segment of the left antenna is about 4·5 mm. long, dark brown with a polished surface crossed by transverse grooves, which become deeper distally. This segment corresponds with the fourth and fifth segments of the right antenna. The sixth segment of the right and the fifth segment of the left antenna are similar, very short, narrow, and pale brown in colour. The seventh segment of the right antenna is shorter and stouter than the sixth segment of the left, which is long and slender. Both these terminal segments are very pale brown and shining. From the inner and posterior aspect a very long colourless seta arises and to its outer side there are two hemispherical prominences on each of which is situated a short transparent conical seta, and still further out is a smaller prominence with a very small conical seta (fig. 2).

They bear a strong resemblance to the antenna of Kolbe's larva of *D. pini.* He considers that the two smooth chitinous basal segments correspond with the two basal segments of the imaginal antenna, which never have hairs or any organs of special sense on them. The transverse grooves of the more distal segments he regards as precursors of those segments of the imago, which carry the organs of special sense.

Accepting Kolbe's explanation, this would give 3 basal segments, 18 subsidiary segments, and 2 terminal segments (23 in all) in this hybrid larva compared with 46, including the large basal segment, in a male imago of *S.* hybr. *hybridus.*

The labrum is asymmetrical, somewhat incompletely developed, and has an aborted process on the left side. The mandibles have the usual cutting edge, but they are firmly welded together by a smooth shining heavily chitinised blackish-brown structure with bosses on its surface, and this accounts for the inability of the larva to feed (fig. 5). Below and behind the mandibles is a large asymmetrical structure with three lobes, which is presumably the lower lip. It is dark brown and has a polished surface. The middle lobe has several deep transverse grooves. It is probably the labium, but there is no trace of palpi or spinneret. The two outer lobes probably represent the maxillae. The smooth one on the right has two or three transverse grooves, but no palpus. That on the left has a wrinkled surface with deep grooves running across it, and from its outer and posterior surface arises a palpus with three segments. The proximal one is long and narrow, the middle one is shorter and broader. The distal segment arises from the rounded end of the middle one and is pointed, ending in two projections, a sharp one and a blunt one resembling a sensory cone (fig. 4).

On each side of the head is an ill-formed compound eye, semilunar in outline. It is black and shining with numerous grooves running more or less transversely across its surface, but no true facets are present. There are six ocelli on each side, those on the left differing a little in size and position from those on the right, of which a figure is given. The lowest ocellus should be a little lower than it is represented in the figure (fig. 3).

The legs are all abnormal. In the normal larva there are three well-defined segments. These are usually called the femur, tibia, and tarsus, although it is more probable that they are precursors of the imaginal tarsus, the other parts being hidden inside the thorax. The normal femur is green tinged with pink posteriorly, the tibia is pink, and the tarsus is deep pink with longitudinal wrinkles. The femur and tibia have a number of small pale mammillae on them, each giving rise to a seta. In this hybrid all parts of the legs are both longer and thicker than those of a normal larva. In the first pair of legs the femur on each side has on the outer aspect a small flat plate of dark brown chitin near the base and another raised one near the distal end. At the distal end of each femur of the second pair of legs there are two minute dots of chitin. Except for their size they are normal in other respects. All the tibiae are very abnormal. The basal part is pink with the usual pale mammillae-bearing setae, but at the distal end of each on the outer aspect is a plate of shining blackish-brown chitin with its surface irregularly ridged and bossed. On the first pair of legs the plate is very large on the right and rather smaller on the left. On the right there is a knob of chitin near the proximal end and on the left there are four knobs running up the outer aspect. On the second pair of legs the plates of chitin are much

smaller. On the third pair the chitinous plates are very large, that on the right being both longer and broader than that on the left. The tarsi are all pale brown, highly polished, and have irregular transverse or longitudinal depressions. Each ends in a single claw, pale brown with a darker tip; that on the left leg of the third pair is, however, short and malformed. The uncontrolled development of chitin on the tibia represents an attempt to form a pupal or imaginal leg, and the highly polished tarsi with their pale brown chitin may also be regarded as an approach to the imaginal state.

On each side of the mesothorax there is a black oblique mark running downwards and forwards and on each side of the metathorax there is a similar, but much smaller, one. They appear to lie in the fourth subsegment. They must be wing buds (fig. 7). The horn is broad and short, being little more than a third of the usual length. It is green instead of blue and has the terminal part red (stippled with black in the figure) (fig. 8). The normal horn is blue with only the extreme tip pink (fig. 9).

The larva shows imaginal characters in its antennae and in possessing compound eyes. The mandibles, maxillae, and labium are abnormal, but their increased size and chitinised condition are imaginal. The chitinous plates on the femora and tibiae and the chitinised tarsi may also be regarded as an approximation to the chitinised condition of the legs of the imago. The black wing buds, which are still just visible in the blown larva, are evidence of an attempt to form imaginal wings.

Its approach to the imaginal condition is less close than that of the larvae of the *M. montanata*, the *Oporinia* hybrids, and the *Bombyx mori*, but is closer than that of the larvae of *D. pini* and the hybrid *Lymantria*. It differs from all the other examples of prothetely in Lepidoptera in the great localised overproduction of ill-organised chitin in the maxillae, labium, mandibles, eyes, and legs.

Increased rate of growth was noteworthy in the larva of *Melanippe montanata*, and the larvae of *D. pini* grew quickly and reached maturity in the same summer instead of hibernating. On the other hand, the larva of the hybrid *hybridus* grew more slowly than the other members of the brood and the larvae of the hybrid *Oporinia* showed a remarkable delay in development. Some disturbance in the rate of growth seems to be usual.

It will be noted that two of the five previous records relate to hybrid larvae, a very high proportion in view of the fact that so few hybrid larvae come under observation. With the addition of this new example half the cases known to me have been hybrids and it seems probable that hybridisation plays some part in the production of prothetely.

Wigglesworth has shown that in the Hemipteron, *Rhodnius prolixus* Stål, the corpus allatum, a gland situated in the head, secretes a hormone which causes moulting, and another hormone, which in the earlier instars inhibits the development of adult characters. Distension of the abdomen after feeding is the stimulus which causes secretion, and the necessary concentration of moulting and inhibitory hormones takes place at a slightly variable time after feeding, the critical period. The inhibitory hormone, however, is only present in low concentration, and is secreted at a later period than the moulting hormone.

If the head is removed from a number of 4th-, 3rd-, 2nd-, and even 1st-stage nymphs around the critical period, some of them suffer a partial or complete metamorphosis, and it is possible to arrange them in an unbroken series with normal nymphs at one end, extreme adult forms at the other end, and all grades of intermediates between. In those showing partial or complete development of adult characters the head has been decapitated after the moulting hormone has been secreted, but before the inhibitory hormone has been secreted or before it has reached its full concentration.
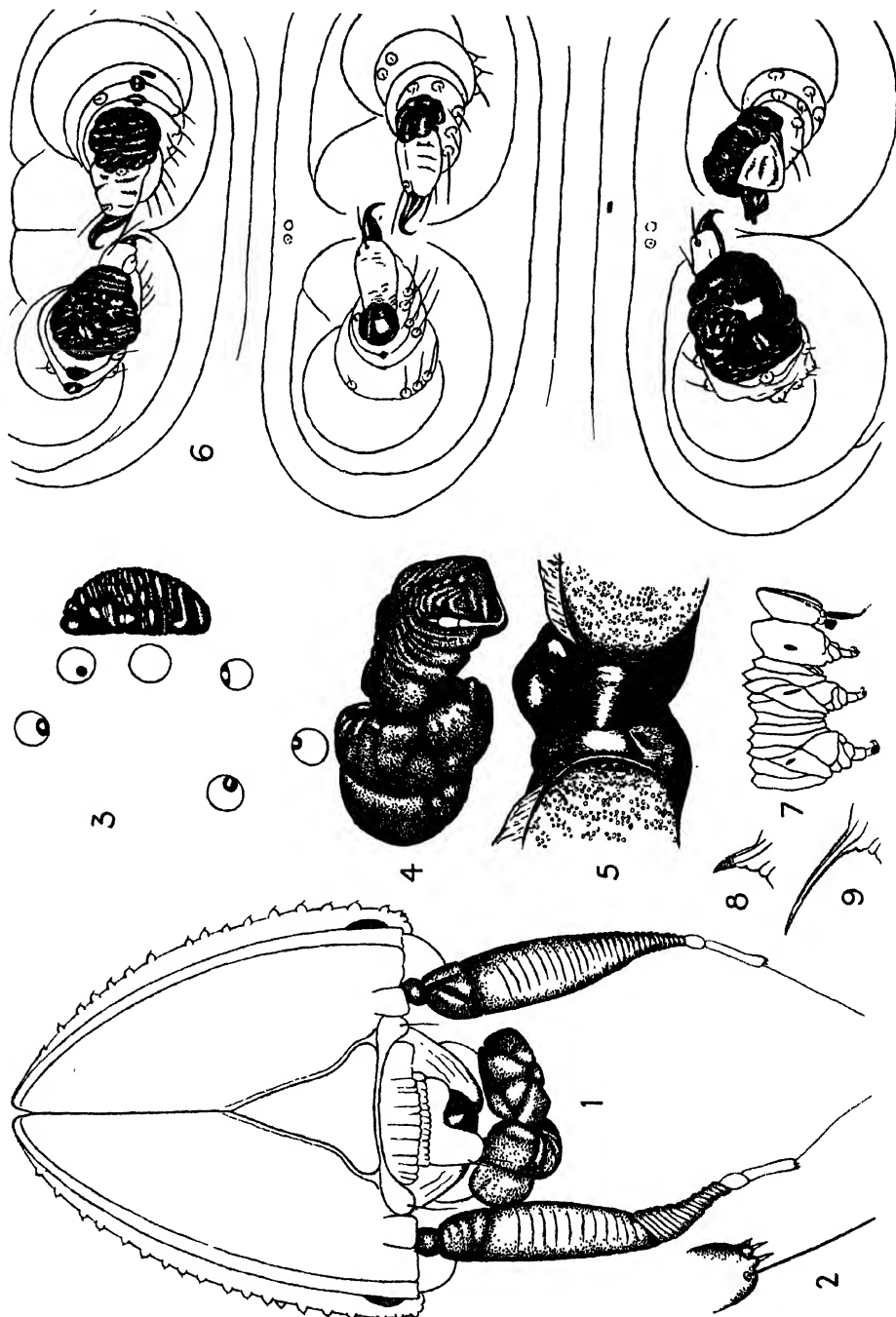
FIGS. 1–9.—1. Front view of head showing abnormal antennae, lower lip, mandibles and compound eyes; 2. distal end of right antenna much magnified, showing only proximal part of long seta; 3. compound eye and ocelli of right side; 4. maxillae and labium seen from below and behind; 5. mandibles seen from below and behind; 6. legs,

If blood is transfused from a 5th-stage nymph decapitated after the critical period into a 4th-stage nymph decapitated 24 hours after feeding, *i.e.* before the critical period, both moult simultaneously and the 4th-stage nymphs are found to have suffered premature metamorphosis and to have developed all the adult characters. If 4th-stage nymphs decapitated 5 days after feeding are united to 5th-stage nymphs decapitated 24 hours after feeding, both moult and while 5th-stage nymphs show slight imperfection of metamorphosis the 4th-stage nymphs show almost complete metamorphosis. If the experiment is repeated with 4th-stage nymphs decapitated 6, 7, and 8 days after feeding, when more inhibitory hormone is present, the 5th-stage nymphs produce adults of both sexes with incompletely formed genitalia and wings intermediate between those of 5th-stage nymphs and adults and the 4th-stage nymphs again develop adult characters, but not as a rule so complete as in the first experiment.

Implantation of the corpus allatum from 3rd- and 4th-stage nymphs in the abdomen of 5th-stage nymphs produces in some cases characters intermediate between those of nymph and adult, a condition not seen in normal *Rhodnius* at any stage.

These experiments suggest that prothetely and hysterotely (metathetely) are due to a disturbance in the hormones, which regulate metamorphosis. For the secretion of the moulting hormone precedes that of the hormone inhibiting metamorphosis, and if the earlier nymphal stages are decapitated before the latter is fully formed, they develop adult characters in greater or lesser degree (prothetely). On the other hand, if 5th-stage or final stage nymphs receive the blood of earlier nymphs containing the inhibitory hormone they develop into adults showing imperfect metamorphosis (hysterotely or metathetely).

Presumably, in lepidopterous larvae which exhibit prothetely, there is a deficient secretion of the hormone which inhibits metamorphosis, but as yet we have no clue to the cause of this naturally-occurring endocrine disorder. Though there is evidence that the corpus allatum in Lepidoptera has the same function as in Hemiptera, the stimulus which causes secretion is still unknown.

These abnormal lepidopterous larvae do not show a condition which is present at any stage of normal development or one which is truly intermediate, and in this respect they differ from the experimental *Rhodnius*. The curiously selective action of the hormone in all the recorded examples, causing partial metamorphosis in certain structures and no change in others, is not easy to account for, and the entirely abnormal growth of the structures showing partial metamorphosis in the *Smerinthus* hybr. *hybridus* larva is difficult to explain in terms of a simple deficiency of inhibitory hormone.

It is possible that the corpus allatum, like the vertebrate pituitary gland, secretes several hormones, and, if this is so, valuable clues to their nature may be derived from the study of natural examples of prothetely, such as the one described in this paper.

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BOOK NOTICE.

Insect Transmission of Plant Diseases. By J. G. LEACH. Pp. xviii + 615, 238 figs., front. 8vo. London (McGraw-Hill), 1940. Price 42s.

This volume is one of the series " McGraw-Hill Publications in the Agricultural Sciences " and the author of it is Professor of Plant Pathology in West Virginia University.

The seventeen chapters are entitled Introduction; the inter-relationships of plants and insects; symbiosis between insects and microorganisms and its significance in plant pathology; the relation of insects to the spread and development of plant diseases; plant diseases caused by toxicogenic insects; insects and bacterial diseases; insects and fungus diseases; insects and virus diseases (2 chapters); insects and phytopathogenic protozoa; mites, nematodes, and other small animals as vectors of plant diseases; the anatomy and physiology of plants in relation to infection and insect vectors; the anatomy and physiology of insects in relation to the transmission of plant diseases; the inocula of plant pathogens in relation to insect transmission; the feeding and breeding habits of insects in relation to the transmission of plant diseases; insect transmission of animal diseases compared with insect transmission of plant diseases; and methods useful in the study of insect transmission of plant diseases.

In an appendix is a series of tables showing diseases and their vectors; insect vectors and the disease they transmit; and a comparison of some fungus diseases in respect to transmission phenomena; virus diseases and bacterial diseases. The book is completed by a glossary and index and at the end of each chapter is a list of literature.

The author " has endeavoured to bring together in one publication the most important contributions " and " to evaluate and interpret the evidence in the light of more recent advances in entomology and plant pathology."

BOOK NOTICE.

The Microscope. By R. M. ALLEN. 8vo. London (Chapman and Hall), 1940. Price 15s. 0d. pp. viii + 286, 18 pls. (col.), 82 figs.

The seven chapters of this book are entitled : historical introduction; optical principles of the microscope; modern instruments; illumination; testing of microscope objectives; getting the most out of the microscope; preparation of material for microscopical examination. The book is completed by a short Bibliography, Glossary and an Index.

The illustrations are mainly concerned with instruments commonly met with in the United States of America, where the book was printed, and the technique described is that evolved in the author's own laboratory.

The book is printed throughout on a coated paper in order to reproduce satisfactorily the many half-tone illustrations printed in the text.

ACTIVITY OF *GLOSSINA PALLIDIPES* AND THE LUNAR CYCLE (DIPTERA)

By F. L. VANDERPLANK, B.Sc.

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Introduction.

THE locality and conditions in which the following experiments have been carried out will be described in a future paper. The observations below are from catches of *Glossina pallidipes* Austen made with bait oxen. Two methods were used :—(1) Moving Rounds : an ox was led along the thicket path and stopped at short intervals to enable the catchers to search for tsetses; (2) Stationary Catches : an ox was tethered at some point along the thicket path and the tsetses caught as they alighted on the animal.

From January to October 1939 moving catches were made practically every day, excepting Saturdays and Sundays, and the stationary catches were made six to eight times a month from 8.0 a.m. to 6.0 p.m. East African Standard Time. From October 1939 to May 1940 the moving catches were made six times a month and the stationary catches daily, except Saturdays and Sundays, from 2.0 p.m. to 5.45 p.m. East African Standard Time.

Examination of the daily male and female totals of *pallidipes* caught revealed that the numbers fluctuated to a 28–29-day cycle, correlated with the lunar cycle.

Observations.

Moving Rounds.

In the first instance the daily total (male and female) catches on days following light nights (*i.e.* during second and third lunar quarters) were tested for significance against the daily total catches on days following dark nights (during the first and fourth lunar quarters). This difference was found to be highly significant.

The mean total catches (male and female) arranged against the lunar phase are shown later in Table II. Since it was desired to be able to correct the old male catch for this phenomenon, the daily total male catches off ox were arranged in the following manner :—commencing with the day following the new moon as day one, the days following were numbered two, three, etc. up to full moon, when the numbering was reversed so that days following nights of equal moonlight received the same numbers. The male *pallidipes* catch per round was then correlated with this ascending magnitude of moonlight. Since the intensity of moonlight arranged in this manner would theoretically give a slightly " S "-curved line, this arrangement will be inaccurate at both extremities. The correlation coefficient (r) obtained was — 0·4236, the number of observations was 282 and P was less than one in a hundred.

Stationary Catches.

These catches were also examined for a significant difference between the mean total (male and female) *pallidipes* caught on days following dark nights (first and fourth quarters of the moon) and the mean total *pallidipes* caught on days following light nights (second and third quarters). The results are set out below in Table I.

TABLE I.

Month	Catches following light nights			Catches following dark nights		
	No. of ¼-hour catches	Total males and females	Mean per 2½ hours	No. of ¼-hour catches	Total caught	Mean per 2½ hours
April . .	31	21	6·8	33	35	10·6
May . .	32	15	4·7	32	22	6·9
June . .	33	16	4·9	31	119	38·4
,, . .	33	37	10·3	33	80	24·2
July . .	30	51	17·0	31	75	24·2
,, . .	31	34	11·0	31	74	23·9
August .	31	89	28·7	30	80	26·7
,, . .	0	—	—	31	84	27·1
September .	44	50	11·4	32	76	23·7
,, .	21	10	4·9	29	164	56·6
,, .	44	80	18·2	31	93	30·0
November .	15	11	7·3	32	32	10·0
,, .	44	47	10·7	41	300	73·2
,, .	44	48	10·9	46	226	49·1
Total .	433	509	11·8	463	1460	31·5

The differences between these means are highly significant.

When the male *pallidipes* catch was correlated with the lunar cycle in the same way as described for the moving rounds above, $r = -0.7845$, and the number of observations was 2277, the results being highly significant. The female catch was treated in the same way and with $r = -0.6956$, and 2277 observations, this result is also highly significant.

Graph.

The graph shows the mean total (male and female) *pallidipes* catch per 7½ hours for both the moving and stationary catches, arranged according to the position of the day, on which they were carried out in relation to the lunar cycle. These means have been based on catches made between January 1939 and the end of July 1940. This graph shows two " S "-shaped curves which would correspond to the expected lunar light of the nights preceding the catch. The data obtained are shown in Table II.

The moving catches show a greater variation in the amplitude of the cycle than the stationary catches. This is due to the fact that more *pallidipes* were taken in the same period of time on the moving catches than on the stationary, because the former method takes non-hungry males searching for females whereas the latter only takes the hungry ones looking for food.

TABLE II.

Lunar cycle, day	¼-hour periods	Stationary, mean total per 7½ hours	¼-hour periods	Moving catches, mean total per 7½ hours
1	150	15·2	45	25·0
2	56	14·9	0	—
3	75	14·3	30	22·0
4	41	11·5	51	18·6
5	89	14·1	93	15·4
6	225	13·8	132	12·3
7	46	11·6	27	13·2
8	63	12·9	0	—
9	75	10·7	21	8·4
10	20	12·1	33	10·1
11	116	12·3	63	16·0
12	110	13·6	99	18·5
13	96	15·3	129	20·3
14	27	16·5	105	26·4
15	132	15·4	84	31·2
16	56	16·1	45	32·4
17	30	17·0	51	35·8
18	42	16·9	24	34·6
19	63	18·6	66	42·4
20	123	19·5	63	49·3
21	93	21·2	141	55·6
22	61	24·3	108	54·3
23	145	26·5	126	55·8
24	131	28·0	0	—
25	52	27·8	21	63·7
26	93	30·4	69	51·2
27	62	25·1	54	47·6
28	230	18·7	81	43·3
29	110	16·6	15	30·0
1	150	15·2	45	25·0
2 etc.	56	14·9	0	—

Activity of pallidipes *at Night.*

The inference to be drawn from the above data is that *G. pallidipes* feeds on moonlight nights and does not feed so freely, if at all, on dark nights. Some data have been collected concerning the activity of *pallidipes* at night.

During April 1940 a moving round was commenced at 9.30 p.m., on the day before full moon, using an adhesive screen. The barrier path was transversed and no *pallidipes* were taken. On the return journey a game path running outside the barrier was used and three male *pallidipes* were taken on the screen. The author and another European accompanying the party were both bitten by tsetses, which were most likely *pallidipes* since *G. swynnertoni* was very scarce in this area. The return journey commenced at 10.30 p.m. and ended at 11.30 p.m.

J. Y. Moggridge, Junior Entomologist of the Department, has reported (unpublished) the taking of male and female *pallidipes* in small numbers at all hours of the night on both moonlight and dark nights at Kilifi, Kenya.

Summary.

(1) An account is given of observations showing that the numbers of *pallidipes* caught on days following moonlight nights are significantly fewer than the numbers caught on days following moonless nights. Two methods of catching *pallidipes*, (*a*) moving round and (*b*) stationary catches, were used and the data from them treated separately.

(2) The results of correlating the *pallidipes* catch with the amount of moonlight on the previous night are given for both moving and stationary catches. The correlations were highly significant.

(3) A table and graph showing the mean total (male and female) *pallidipes* catches against the corresponding phases of the moon for both methods of catching are given. The graph shows an " S "-shaped curve in both cases.

(4) The inference is drawn that *pallidipes* is more active on moonlight nights than dark nights and so less active during the following day, and a few observations on the taking of *pallidipes* at night are mentioned.

GRAPH.—Mean *G. pallidipes* catch in relation to lunar cycle.

STUDIES ON THE CHEMISTRY OF PIGMENTS IN THE LEPIDOPTERA, WITH REFERENCE TO THEIR BEARING ON SYSTEMATICS. 1. THE ANTHOXANTHINS

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CONTENTS.

1. Introduction to the series.

THE chemistry of the pigments occurring in the Lepidoptera has been studied on a number of occasions (for a summary of the literature see Baylis 1924, Verne 1930, Imms 1937, Wigglesworth 1939). It must be admitted, however, that the subject has received far less attention than it deserves in view of its interest. Furthermore, it has rarely been applied to classification and phylogeny. Indeed this seems to have been attempted on three occasions only, by Cockayne (1924) and by Ford (1938a and 1940). Yet with the partial exception of the last, in which a short section was devoted to this topic, these articles were concerned mainly with work devoted to other ends. A survey of the chemistry of pigments in its relation to the classification of the Lepidoptera is much to be desired, and the present series of papers is an attempt to meet this need.

Previous investigators have devoted themselves almost wholly to the chemical analysis of some given pigment in a few species, as in the work of Wieland and others (1933) and of Schöpf and Becker (1933). To this, two notable exceptions must be made. The first of these is the well-known and fundamental work of Hopkins (1895). This was devoted mainly to an investigation of the pterine pigments (p. 67) of the PIERIDAE, which he studied in a number of species. But, in addition, he briefly discussed various types of pigments in several other families, and pointed out that superficially similar effects may be produced in mimic and model by different chemical means. However, the bearing of chemistry on classification was hardly within the scope of his work. Indeed his only reference to this topic seems to be the statement that : " In the apparently strict confinement of these special pigments [1] to the PIERIDAE, we have interesting evidence justifying the customary classification of these insects as a natural group." It may be noticed, however, that the pigments of the PIERIDAE are less closely restricted to that family than Hopkins supposed. It seems highly probable that pterines occur widely elsewhere in the Lepido-

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[1] Uric acid, and its soluble murexide-yielding derivatives.

ptera (p. 67); while it will be shown in a later paper that the special red pigment which he noticed in certain PAPILIONIDAE is found in some PIERIDAE. Further, it will be demonstrated in the present account that the peculiar pigment (now recognised as a flavone) which he encountered in the Satyrid *Arge* (= *Melanargia*) *galathea* L. occurs also in the latter family, which he studied so fully and successfully, and is, indeed, characteristic of certain Pierine genera. The second investigation to which special attention must be drawn is that of Cockayne (1924), who made an extensive survey of the distribution in the Lepidoptera of the pigments fluorescent in ultra-violet light. His main object was to provide detailed information on their occurrence throughout the Order : a task which he performed in a remarkably thorough manner. But, in addition, his data enabled him to make a number of useful suggestions on classification and phylogeny.

Thus it comes about that to apply chemical methods to the study of systematics in the Lepidoptera is largely to break new ground. I am conscious that the present attempt suffers from the defects inherent in the preliminary treatment of any rather extensive subject. Any detailed investigation of the occurrence of even a single type of pigment in an Order so large as the Lepidoptera would be an immense task, for which I cannot spare the time. Consequently, it has seemed well to proceed upon the following lines. Each pigment has been studied separately, and the work upon it divided into two sections. First, I have examined as thoroughly as possible its distribution within a few convenient families. The data so obtained have then been analysed with respect to the information that they provide both on classification and phylogeny. These detailed studies may be regarded as indicating the kind of results to be obtained from such investigations. Secondly, I have surveyed more widely the occurrence of the pigment in question, but in much less detail : sufficient only to indicate its existence in a number of other groups, for which purpose I have tested a limited selection of species within each. Using such information, those working on one of them may find, for example, that two chemically distinct types of a pigment exist among the insects with which they deal. Seeing that helpful results have been obtained by the application of this fact elsewhere in the Order, they may feel inclined to use it in their own studies.

Several different pigments have already been examined in this way. It is proposed to publish a short series of papers each devoted to one of them, of which this (on the anthoxanthins) is the first. The last is to contain a general summary of the more important results described in the Series. The choice of pigments is restricted by a severe technical limitation. It must be possible to examine them without injuring the specimens studied, otherwise a sufficiently wide range of material could never be obtained. Although confirmatory tests in which this condition is not fulfilled may also be applied, it is one which must be observed in general. Helpful and generous as I have invariably found those in charge of museums to be, it would not be possible for them to facilitate investigations which involve a considerable destruction of the material in their care. It will, however, be realised how severe a handicap on chemical methods such considerations impose.

Naturally it is not suggested that chemistry provides a less fallible criterion of affinity than does structure. The basis of classification should always be as wide as possible, embracing as many characters as are available for study, and to these, chemical distinctions make an addition of some value. In many instances also they corroborate the current classification of the Lepidoptera on evidence wholly distinct from that upon which it has been constructed.

2. Introduction to the present paper.

The anthoxanthins are a group of sap-soluble plant pigments responsible for a series of colours ranging from ivory to deep yellow. Their structure is of the type :

Flavone (apigenin)   Flavonol (quercetin)
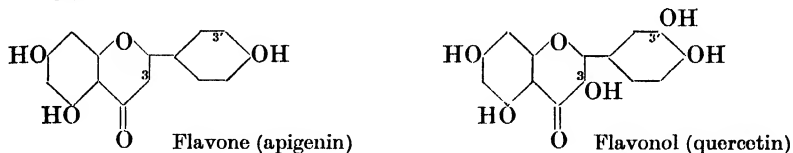
They fall into two classes : the flavones with a hydrogen atom at position 3 in the pyrone ring, and the flavonols in which this is replaced by a hydroxyl. The various types within each group differ from one another by modifications of the side phenyl ring. For example, a hydroxyl substituted at 3′ in the flavone illustrated (to give a phenyl ring of the type selected for the flavonol) would convert the ivory apigenin into the yellow luteolin.

These pigments are widespread in plants, but it seems that animals are unable to manufacture them and must obtain them from their food. The ability to digest and use them unaltered is not common, for in general the anthoxanthins are rare in animals. Their existence in the Lepidoptera was first recognised by Thomson (1926a) in the Satyrine *Arge galathea* L. He demonstrated also that the same pigment is present in the grass *Dactylis glomerata* upon which the larvae feed (Thomson, 1926b). Since that time Manunta (1935) has shown that anthoxanthins contribute to the cocoon colours of some silkworm races, and that they are found in the blood and epidermis of larvae of the genus *Pieris*. This seems to comprise all the available information on the matter, and it is generally regarded as one on which little is known. Thus Imms (1937 : 189) says : " It is probable that pigments of the flavone type are widely spread among insects, but the subject has been very little studied "; while Wigglesworth (1939 : 335) remarks : " Anthocyanins [2] and flavones, which are important flower pigments, are not very common among insects." The results recorded in the present paper, in fact, indicate that anthoxanthins are by no means rare in the Lepidoptera. Even here, it appears that the white and yellow colours are usually produced solely by substances very different from them in their origin and chemistry. It is probable that these are " pterines," which are built up from uric acid and, consequently, are manufactured by the insects themselves. They are exemplified by the white " leucopterin " ($C_{19}H_{19}O_{11}N_{15}$) isolated by Wieland and others (1933) from *Pieris brassicae* L., and the yellow " xanthopterin " ($C_{19}H_{19}O_7N_{15}$) obtained by Schöpf and Becker (1933) from the male *Gonepteryx rhamni* L. Hopkins (1895) had regarded the white pigment of the PIERIDAE as uric acid, while xanthopterin seems to be the derivative which he named " lepidotic acid." He considered that uric acid and its soluble murexide-producing derivatives are almost restricted to the PIERIDAE. Except for *Papilio machaon* L., in which he found that the yellow substance has entirely different properties from the uric acid group, he does not state in what members of other families he investigated the nature of white and yellow pigments. However, white pigments exactly resembling those of the PIERIDAE are extremely widespread

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[2] These are sap-soluble glycosides giving a range of colours from scarlet, through purple, to blue. They differ only from the anthoxanthins in the substitution of a hydrogen for an oxygen atom at position 4, to give a γ-pyran instead of a γ-pyrone ring.

in the Lepidoptera. Consequently, one may fully expect to find that many of them are pterines of some type. Their precise nature is irrelevant to the present work, which is concerned to determine whether or not they contain anthoxanthins.

In general, even when anthoxanthins are present they are not alone responsible for the white and yellow colours of the Lepidoptera. It is usual to find that these are due also to other pigments in addition, and this seems always to be true in the PIERIDAE.

The existence of anthoxanthins as wing pigments may be detected by two tests of the type used to recognise them in flowers (Scott-Moncrieff, 1936). First, a yellow colour is produced on fuming the wings with strong ammonia. This is due to the fact that the flavones and flavonols combine with ammonia to form coloured salts. In the Lepidoptera these are very unstable, so that the specimen speedily returns to its original condition after treatment. Consequently, it is uninjured by the process. This reaction is a highly diagnostic and sensitive one. It suffices to detect traces of anthoxanthins when present in a single specimen. In certain circumstances, however, it is inapplicable : when the flavone concerned is itself deep yellow, or when it is obscured by other pigments. In these conditions another method is used. The wings are removed, cut up if necessary, and soaked for at least forty-eight hours in ethyl acetate, which extracts anthoxanthins but not pterines. The colourless solution so obtained is filtered and shaken with an aqueous solution of sodium carbonate, when a deep yellow colour is produced if flavones or flavonols are present. If they are not, the liquid remains colourless. As already explained, a method such as this, which destroys the specimen, cannot be widely used. It is, however, valuable in the circumstances indicated. Moreover, it admits of the accumulation of a detectable amount of pigment from a number of specimens in each of which it exists in a small quantity only. However, it is less sensitive than the former test. The supply of anthoxanthin in the wings of *Enantia licinia* Cr. is considerable, for a deep yellow colour is obtained on fuming them with ammonia. Yet a single specimen does not provide enough pigment to give a positive reaction on extracting with ethyl acetate, though three specimens do contain sufficient to produce a detectable effect. So does even a single specimen of the Satyrine *Arge galathea*.

In general, therefore, I have been able to study only those species possessing colours ranging from white to light yellow. Those in which dark yellow pigment alone is available have been used when it is particularly desirable to establish its nature, provided that sufficient material exists. In all important instances both types of test have been employed where possible. Further, I have made a constant practice of examining several specimens of each species. These have always given consistent results, provided that they are in fairly fresh condition; anthoxanthins are often less easy to demonstrate in worn specimens. On the other hand, the length of time that the insects have been kept in collections appears to be irrelevant. Thus these pigments can be detected as easily in specimens of *Enantia licinia* Cr., preserved at Oxford, which were captured by Burchell in 1827 as in those caught in the present century.

As already indicated, great numbers of species do not use anthoxanthin pigments to form their white or yellow colours. Yet many of them must feed on plants rich in these substances. Either they are unable to digest, or to utilise, them unaltered, or both. The first alternative is inherently possible, for failure to digest a particular type of pigment has been demonstrated

in other circumstances. Thus Gerould (1921) showed that in *Colias philodice* Godt., a single genetic factor, recessive in effect, prevents the digestion of all pigments of the chlorophyll group except the blue-green chlorophyll-A. Similarly, a single factor, also recessive in operation, prevents the Amphipod Crustacean *Gammarus chevreuxi* from digesting carotin, though not from using it when supplied by other means : *i.e.*, in the cytoplasm of the egg (for a full account, see Ford, 1938*b* : 161–65). On the other hand, Manunta (1935) demonstrated that anthoxanthins exist in the blood and epidermis of *Pieris* larvae. Yet the white pigment in the adults of this genus contains none (see p. 72). Furthermore, flavones are present in the white or yellow wings of the genus *Enantia* (p. 76), but in the exposed parts only (though no such restriction occurs in other genera) : the areas hidden by the overlap of the fore- and hind-wings are coloured white by pterins in the normal Pierine manner. These two observations tend to show that it is the utilisation rather than the digestion of the flavones and flavonols which determines their presence in the Lepidoptera. Such considerations indicate that their occurrence is not dependent merely upon the type of larval food : a fact sufficiently attested by their presence or absence throughout large groups with varied food-plants (e.g., *Graphium* compared with *Papilio*). Furthermore, numerous instances exist of two species one of which possesses anthoxanthin pigment in the scales while the other does not, though they have the same food-plant (e.g., *Pararge egeria* L. and *Coenonympha pamphilus* L. Anthoxanthins are absent in the former but present in the latter. They both feed in grasses, especially *Poa annua*, on which each has been reared).

I have made rather thorough studies of the occurrence of anthoxanthins in the PAPILIONIDAE and the PIERIDAE, and have used the data so obtained to throw light on the systematics of these two families. I have also surveyed a number of other groups of Lepidoptera, but in sufficient detail only to indicate the presence of anthoxanthins in them, according to the plan already described. The work has been conducted on the material in the Hope Department of Entomology at Oxford, and in the Department of Entomology at the British Museum (Natural History). I have also had the benefit of examining additional species in the Rothschild Museum at Tring (now a branch of the British Museum). These three collections together contain so overwhelming a proportion of the Lepidoptera of the world preserved in Great Britain that to examine others after them would be unnecessary.

They have all been so good as to give me the benefit of their opinion on this paper.   I have had the advantage of discussing the bearing of chemistry on classification in the PAPILIONIDAE with Dr. K. Jordan, F.R.S.   Mr. W. H. T. Tams has been so kind as to give me his help in the section which deals with the moths.

1 am much indebted to Dr. B. K. Blount for his kind help on chemical questions.   I have had the pleasure of discussing this paper with Prof. R. A. Fisher, F.R.S.   His suggestions, and the interest which he has taken in the work, have been a great encouragement to me.   I should like to thank Prof. E. S. Goodrich, F.R.S., for his helpful criticism.

3. Anthoxanthins in the family PIERIDAE.

The PIERIDAE comprise the great assemblage of the white and sulphur butterflies and their allies. 1 have followed, in my study of them, the most modern classification dealing with the family throughout its entire range : that of Talbot (1932–35) in *Lepidopterorum Catalogus*.   In a still more recent work, the same author (Talbot, 1939) has made certain minor adjustments to his previous scheme.   However, as he was there treating of the butterflies of British India alone, it has seemed well to follow the former work throughout.   It would be in several ways unsatisfactory to modify a small section only of the arrangement; and there is some advantage in basing the present discussion on a single well-known and authoritative plan.

In *Lepidopterorum Catalogus* the family is divided into five subfamilies, in the following order :—

1. PSEUDOPONTIINAE E. Reut.	(1 genus)	
2. DISMORPHIINAE Hübn.	(3 genera)	
3. PIERINAE Sw.	(43 ,,)	
4. TERACOLINAE Auriv.	(9 ,,)	
5. COLIADINAE Auriv.	(11 ,,)	

The first of these contains but a single genus and species, the unique African *Pseudopontia paradoxa* Feld.   I have not detected anthoxanthins in this form, and indeed its scales are greatly reduced.   The second comprises the peculiar central and South American genera *Dismorphia* (now to be sub-divided, p. 74) and *Pseudopieris* and, in addition, the Palaearctic " Wood Whites " (*Leptidea*) : 108 species in all.   They are highly abnormal Pierids.   The remaining three subfamilies must include many hundreds of species.

It may be added that Talbot (1939) no longer distinguishes the TERACOLINAE as a separate subfamily but combines them with the COLIADINAE. However, as will later appear (p. 77), there seems to be some advantage in separating the PIERINAE and TERACOLINAE, principally feeding on Cruciferae and Capparidaceae respectively, from the COLIADINAE (in the strict sense) which feed on Leguminosae.   In addition, to do so is in accord with the classification which has been adopted here.

I have elsewhere reported the discovery of anthoxanthin pigments in some species of the subfamily DISMORPHIINAE, and their apparent absence elsewhere in the PIERIDAE, and have commented on the significance of this fact (Ford, 1940).   A great deal more information on the subject is now available.

First, it may be well to consider the negative evidence derived from the remainder of the PIERIDAE.   Time would not have allowed me to examine every suitable species available in the subfamilies PIERINAE, TERACOLINAE, and

TABLE 1.

Genera and species tested for anthoxanthins in the subfamily PIERINAE.

Genus	Species	Genus	Species
Neophasia	*menapia* Feld.	*Appias*	*lyncida* Cr.
Catasticta	*corcyra* Feld.		*celestina* Bdv.
	ctemene Hew.		*cardena* Hew.
	sisamnus Fb.		*paulina* Cr.
	flisa H.-S.		*leis* Hbn.
	philone Feld.		*epaphia* Cr.
	teutila Dbl.	*Phrissura*	*aegis* Feld.
	tomyris Feld.	*Saletara*	*panda* Godt.
	toca Dbl.	*Andropodum*	*drusilla* Cr.
Leodonta	*dysoni* Dbl.	*Anapheis*	*creona* Cr.
Archonias	*tereas* Godt.		*grandidieri* Mab.
Charonias	*theano* Bdv.		*antsianaka* Ward
Percute	*charops* Bdv.	*Belenois*	*raffrayi* Ob.
Leptophobia	*erinna* Hopf		*margaritacea* Shpe.
	penthica Koll.		*calypso* Drury
Melete	*lycimnia* Cr.	*Dixeia*	*orbona* Geyer
	leucanthe Feld.		*pigea* Bdv.
Tatochila	*autodice* Hb.		*charina* Bdv.
Phulia	*nymphula* Blanch.	*Ascia*	*monuste* L.
Piercolias	*huanaco* Stgr.		*sevata* Feld.
Baltia	*shawi* Bates		*buniae* Hbn.
Mesapia	*peloria* Hew.		*amaryllis* Fb.
Aporia	*crataegi* L.	*Itaballia*	*demophile* L.
	soracta Moore		*pandosia* Hew.
	delavayi Ob.	*Perrhybris*	*pyrrha* Cr.
	largeteaui Ob.		*lorena* Hew.
Delias	*georgina* Feld.	*Pieris*	*brassicae* L.
	castaneus Kenr.		*candida* Sparrm.
	bornemanni Ribbe		*rapae* L.
	bakeri Kenr.		*extensa* Pouj.
	callima R. & J.		*melete* Men.
	kummeri Ribbe		*napi* L.
	oryntion G. & S.		*mandela* Feld.
	nigrina Fb.	*Mylothris*	*chloris* Fb.
	henningia Esch.		*rembina* Ploetz
	crithoe Bdv.		*poppea* Karsch.
	aglaia L.		*agathina* Cr.
	egialea Cr.		*rueppellii* G. Koch
	thysbe Cr.		*phileris* Bdv.
	descombesi Bdv.		*trimenia* Btl.
	belisama Cr.		*sagala* Sm.
	eumolpe Sm.	*Nina*	*nina* Fab.
	aruna Bdv.	*Elodina*	*hypatia* Feld.
	aganippe Don.		*parthia* Hew.
	harpalyce Don.	*Leuciacria*	*acuta* R. & J.
	agostina Hew.	*Synchloe*	*callidice* Esp.
	ennia Wall.	*Pontia*	*daplidice* L.
s.g. *Cathaemia*	*eucharis* Drury		*helice* L.
	hyparete L.	*Pontieuchloia*	*chloridice* Hb.
	mysis L.	*Zegris*	*eupheme* Esp.
	argenthona Fb.	*Euchloe*	*ausonia* Hbn.
Cepora	*nerissa* Fb.		*belemia* Esp.
	nadina H. Luc.		*creusa* Dbl.
	perimale Don.	*Elphinstonia*	*tagis* Hbn.
	boisduvaliana Feld.	*Anthocharis*	*cardamines* L.
Aoa	*affinis* Voll.		*belia* L.
Udaiana	*cynis* Hew.		*sara* Bdv.
Ixias	*pyrene* L.	**s.g.** *Falcapica*	*genutia* Fab.
Prioneris	*sita* Feld.		*scolymus* Btl.
	autothisbe Hb.	*Pinacopteryx*	*eriphia* Godt.
	hypsipyle Weym.		
Appias	*libythea* Fb.	**43 genera**	**122 species**

TABLE 2.

Genera and species tested for anthoxanthins in the subfamily TERACOLINAE.

Genus	Species	Genus	Species
Eroessa	*chilensis* Guér.	*Colotis*	*daira* Klug
Hesperocharis	*nera* Hew.		*etrida* Bdv.
	anguitia Godt.		*evenina* Wllgr.
	erota Luc.		*eris* Klug
	marshalii Guér.		*subfasciatus* Sws.
s.g. *Cunizza*	*hirlanda* Stoll	s.g. *Calopieris*	*eulimene* Klug
s.g. *Mathania*	*leucothea* Molina	*Gideona*	*lucasi* Grand.
Eucheira	*socialis* Westw.	*Eronia*	*cleodora* Hbn.
Colotis	*phisadia* Godt.		*leda* Bdv.
	vestalis Btl.	*Nepheronia*	*argia* Fb.
	vesta Riche		*buqueti* Bdv.
	celimene Luc.		*pharis* Bdv.
	halimede Klug		*thalassina* Bdv.
	pleione Klug		*avatar* Moore
	ione Godt.	*Pareronia*	*hippia* Fab.
	hetaera Gerst.	*Hebomoia*	*glaucippe* L.
	danae Fb.		
	eucharis Fb.		
	evippe L.	9 genera	35 species

COLIADINAE. I have therefore taken samples from every one of the sixty-three genera into which they are divided by Talbot (1932–35). In all but the smallest of these I have studied numerous species, making sure that those selected are widely scattered through the genus, and that they are drawn from each subgenus suitable for study where such exist. The genera and species (amounting to 63 and 195 respectively) so examined are given in Tables 1–3. I may perhaps claim that this represents a fairly thorough survey of the three subfamilies in question.

In no instances save two have anthoxanthin pigments been detected in them. These exceptions are first, *Gandaca* (COLIADINAE), a genus of a single species (*G. harina* Horsf.) containing abundant pigment of the flavone type.[3] The problems which it presents will be reserved for discussion later (p. 77). Secondly, the African *Eronia cleodora* Hbn. (TERACOLINAE), in which, however, the situation is very different, since the quantity of anthoxanthin pigment which it contains is quite minute. It might easily escape notice, as a barely detectable trace only can be demonstrated, by the ammonia method, in none but very fresh specimens. The situation, therefore, is quite unlike that found in the other PIERIDAE which possess these pigments, for in them they are easily recognised. I was able to obtain 18 specimens of *E. cleodora* for extraction with ethyl acetate, but the quantity of pigment is too small to be detected by this means. Consequently it cannot be as much as one-sixth of that present in *Enantia licinia* (see p. 76), a smaller butterfly, and may be much less than this. Interest naturally attaches to the only other species of the genus *Eronia*. This is *E. leda* Bdv. Unfortunately the males are bright yellow insects with orange tips to the fore-wings, so that the ammonia test is inapplicable to them. The females are paler, but they give no reaction by this method : they are, however, too deeply coloured for a slight effect to be detected. Eighteen

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[3] On extraction with ethyl acetate, 3 specimens produce a detectable effect, so that the quantity of anthoxanthin is nearly the same as in the *Enantia* species (p. 76).

TABLE 3.

Genera and species tested for anthoxanthins in the subfamily COLIADINAE.

Genus	Species	Genus	Species
Colias	*palaeno* L.	*Gandaca*	*harina* Horsf.
	philodice Godt.	*Eurema*	*hecabe* L.
	hyale L.		*candida* Cr.
	electo L.		*daira* Godt.
	e. croceus Fourc.		*agave* Cr.
	dimera D. & H.		*elathea* Cr.
	vautieri Guer.		*phiale* Cr.
Catopsilia	*pomona* Fb.		*arbela* Gey.
	sylla L.		*gratiosa* D. & H.
	gorgophone Bdv.		*mexicana* Bdv.
	pyranthe L.		*adamsi* Lathy
	florella Fb.		*albula* Cr.
Anteos	*clorinde* Godt.		*deva* Dbl.
Gonepteryx	*rhamni* L.		*priddyi* Lathy
	cleopatra L.		*lisa* B. & L.
Dercas	*lycorias* Dbl.		*nise* Cr.
Phoebis	*sennae* L.		*messalina* Fab.
	argante Fab.	*Nathalis*	*iole* Bdv.
Kricogonia	*castalis* Fab.		
Leucidia	*brephos* Hbn.	11 genera	38 species

specimens were available for pigment extraction, but the result was negative. Therefore it is only possible to assert that the wings of *E. leda* cannot contain more than a trace of pigment of the flavone type, and may contain none. *Gandaca harina* and *Eronia cleodora* are the only species among the PIERIDAE in which I have found anthoxanthins outside the genera of which such pigments are characteristic : 2 out of 233 species.

Attention may now be devoted to the remaining subfamily, the DISMORPHIINAE. Talbot (1932–35) includes 102 species in the genus *Dismorphia*, some of which I find contain anthoxanthins. So too do all three species (see Table 4) of the closely allied, and also neotropical, genus *Pseudopieris*. These two genera are exceedingly distinct from the remaining PIERIDAE and many, but not all, of the species are mimetic. The question of their relation to the rest of the group is therefore one of considerable interest. Structural considerations have led to the rather remarkable conclusion that they are allied to the Palaearctic " Wood Whites " *Leptidea*. Thus Röber (1924 : 98) says : " With this genus [*Pseudopieris*] begins a small group of genera which cannot with certainty be reckoned Pierids and yet can still less be associated with any other family. . . . Their nearest representatives are the Palaearctic *Leptidea* and perhaps *Pseudopontia* from West Africa." Talbot (*loc. cit.*) goes further, and includes *Leptidea* in the subfamily DISMORPHIINAE. Doubtless he is right, for the genus contains abundant anthoxanthins, a condition never found elsewhere in the PIERIDAE (save in *Gandaca*, p. 72) outside the neotropical DISMORPHIINAE. On extraction with ethyl acetate, three specimens of *Leptidea sinapis* provide a sufficient quantity of anthoxanthin to produce a just detectable effect. The amount present is therefore approximately the same as in *Enantia* (pp. 74–76) and *Pseudopieris* (for I obtained a similar result on extracting anthoxanthins from 3 specimens of *P. nehamia*). Antho-

xanthins are easily detected in all three species of *Leptidea* [4] (see Table 4), indicating that its occurrence is fundamental to the genus and not to be treated as a stray exception. It will be noticed that chemical considerations here support in a striking manner an affinity suggested on purely structural grounds.

Having established these facts, the distribution of anthoxanthins within the genus *Dismorphia* became a matter of importance. Would the species containing them be scattered at random on the present classification, or would they fall into a more or less compact group? The latter alternative has proved correct. It indicates a close correlation between the classificatory value of structural and physiological characters in these insects. I have examined every species of *Dismorphia* suitable for study to which I have had access, amounting to 50 out of 102. Of these, twelve contain anthoxanthins and, save for the interpolation of *thermesia* Godt. (see below), they all fall together at the beginning of the genus. Not a single species possesses these pigments among the 37 tested which follow them (see Table 4).

It is a remarkable fact that in a family such as the PIERIDAE, in which pterins are normally responsible for the white and yellow colours, there should exist a group of species which possess pigments differing from them so profoundly in chemistry and origin as the anthoxanthins. When it is further considered that this distinction is intimately related to the accepted classification, though this was devised in ignorance of it, it may be seen that the difference involved is an important one and far greater than any usually to be found between related genera. It is plain therefore that the group of *Dismorphia* species which contain anthoxanthins should be separated generically from the remainder. As pointed out to me by Mr. A. G. Gabriel, a generic name suitable for them already exists. This is *Enantia* (Hubn., 1819, *Verz. bek. Schmett.* : 96) with *licinia* Cr. as type species. *Dismorphia* (Hübn., 1816, *ibid.* : 10), with *laia* Cr. as type, is applicable to the remaining, and much larger, section of the present genus. It is not in their chemistry alone that *Enantia* and *Dismorphia* can be distinguished. The former genus contains species whose ground-colour is always pale, ranging from ivory to deep yellow, sometimes flushed with orange. Also they are marked with black in a fairly regular manner. The latter comprises very varied forms, many being mimetic, but none having quite the *Enantia* colour-pattern.

Reference to Table 4 will show that among the species at present placed in *Enantia* is one, *thermesia* Godt., which must have been classified incorrectly. It is clearly to be distinguished from them because it contains no anthoxanthins. It was on this chemical evidence that the error was detected, but further inspection reveals other differences. On the upperside, the male bears a dark transverse bar across the disc of the fore-wings, and a brown oblong scent-patch near the costa of the hind-wings. Neither of these characters occurs in *Enantia*, but they are found in several *Dismorphia* species. If *thermesia* be placed in the latter genus between *pallidula* Btl. and *lysis* Hew., it will be found to accord very well with its new position. In the male, both these insects possess the brown scent-patch on the hind-wings, and the transverse band is seen as a dark mark on the brownish-black fore-wings of *pallidula* while it invades the white discal region of *lysis*. All three are black (or brownish) and white species; furthermore, the shape of *thermesia* and *lysis* is very similar in both sexes.

[4] Röber (1907–8) regards *L. amurensis* Men. as specifically distinct, making a fourth *Leptidea*. However, Talbot (*loc. cit.*) treats it as a subspecies of *L. sinapis* L. For my purpose the point is immaterial, since *L. amurensis* contains anthoxanthins as do the rest of the genus.

TABLE 4.

The genera and species of the subfamily DISMORPHIINAE arranged according to Talbot (1932–35). $+$ = anthoxanthins present, $-$ = anthoxanthins absent. Unmarked species have not been tested.

1. *Dismorphia* Hbn.

1. *flavia* Feld.	$+$
2. *psamathe* Fb.	$+$
3. *acutipennis* Btl.	$+$
4. *mercenaria* Feld.	$+$
5. *licinia* Cr.	$+$
6. *lina* Herbst	
7. *aphrodite* Feld.	$+$
8. *marion* G. & S.	$+$
9. *thermesia* Godt.	
10. *limnorina* Feld.	$+$
11. *dilis* Bdv.	
12. *dissimulata* d'Almeida	
13. *theugenis* Dbl.	$+$
14. *melite* L.	$+$
15. *cornelia* Feld.	$+$
16. *albania* Bates	$+$
17. *mirandola* Hew.	
18. *altis* Fassl	
19. *carthesis* Hew.	
20. *idonia* Hew.	
21. *zaela* Hew.	
22. *arcadia* Feld.	$-$
23. *lucilla* Btl.	
24. *crisia* Drury	$-$
25. *core* Feld.	$-$
26. *medora* Dbl.	$-$
27. *albimacula* Röb.	
28. *ideae* Fassl	
29. *proserpina* Sm. & Kby.	
30. *zathoe* Hew.	
31. *lelex* Hew.	$-$
32. *pimpla* Hopff.	$-$
33. *pallidula* Btl.	$-$
34. *lysis* Hew.	$-$
35. *foedora* H. Luc.	$-$
36. *virgo* Bates	$-$
37. *lua* Hew.	$-$
38. *garleppi* Stgr.	$-$
39. *lycosura* Hew.	$-$
40. *schausii* Dogn.	
41. *leonora* Hew.	$-$
42. *macasana* Strand	
43. *niepelti* Wegm.	
44. *lewyi* Luc.	$-$
45. *dolorita* Fassl	$-$
46. *critomedia* Geyer	$-$
47. *euryope* H. Luc.	$-$
48. *ines* Röb.	$-$
49. *oreas* Salv.	
50. *lygdamis* Hew.	$-$
51. *hyposticta* Feld.	
52. *manuelita* Fassl	
53. *hippotas* Hew.	$-$
54. *abilene* Hew.	$-$
55. *teresa* Hew.	$-$
56. *melia* Godt.	$-$
57. *larunda* Hew.	

58. *spio* Godt.	
59. *cubana* H.-Sch.	
60. *lysianax* Hew.	
61. *tricolor* Sm. & Kby.	
62. *spectabilis* Avin.	
63. *mechanitina* Rob.	
64. *xanthone* Röb.	
65. *amphione* Cr.	$-$
66. *laia* Cr.	$-$
67. *astynome* Dalm.	$-$
68. *astyocha* Hb.	
69. *deione* Hew.	$-$
70. *eunoe* Dbl.	
71. *sororna* Btl.	
72. *myris* G. & S.	
73. *cordillera* Feld.	
74. *orise* Bdv.	$-$
75. *rhetes* Hew.	
76. *clio* Cr.	
77. *siloe* Hew.	
78. *theucharila* Dbl.	
79. *lysinoe* Hew.	
80. *lysinoides* Stgr.	
81. *erythoe* Bates	
82. *pellucida* Rob.	
83. *batesi* Röb.	
84. *leuconoe* Bates	$-$
85. *fortunata* H. Luc.	$-$
86. *ribbei* G. & S.	
87. *alterata* Btl.	
88. *antherize* Hew.	
89. *avonia* Hew.	
90. *werneri* Hering	
91. *limonea* Btl.	
92. *leuconia* Btl.	
93. *pinthaeus* L.	$-$
94. *ithomia* Hew.	
95. *theaphina* Btl.	
96. *methymna* Godt.	
97. *cyra* Dbl.	
98. *naphra* Herr.-S.	
99. *elongatus* Goeze	
100. *nemesis* Latr.	$-$
101. *cinerascens* Salv.	$-$
102. *poasina* Schs.	

2. *Pseudopieris* G. & S.

1. *nehemia* Bdv.	$+$
2. *penia* Hopff.	$+$
3. *limbalis* Rob.	$+$

3. *Leptidia* Billb.

1. *sinapis* L.	$+$
(*amurensis* Men.)	$+$
2. *duponcheli* Stgr.	$+$
3. *gigantea* Leech	$+$

D 3

With the above adjustment, and following the order of species in the sub-family DISMORPHIINAE as adopted in *Lepidopterorum Catalogus*, one obtains four genera, *Enantia, Dismorphia, Pseudopieris*, and *Leptidea*, three of which without exception contain flavones, while one, the second, without exception, does not. Clearly this arrangement is unnatural. However, if *Leptidea* be placed first and *Pseudopieris* second, all irregularities are removed. There are then three consecutive genera possessing flavones, preceding one which, like the normal Pierine genera that follow it, is without them. Also by placing the Palaearctic *Leptidea* first, the neotropical genera can be kept together.

I shall now consider the genus *Enantia* in detail. Since the publication of the sections on the PIERIDAE in *Lepidopterorum Catalogus*, Talbot has come to the conclusion that some of the forms there separated as species are of subspecific rank only. This arrangement is now adopted at the British Museum, and should be substituted for that previously published. It in no way affects the conclusions reached in this paper. The new system is given in Table 5.

TABLE 5.

The genus *Enantia* Hbn.

Species	Subspecies
licinia Cr.	*psamathe* Fabr.
	mercenaria Feld.
	licinia Cr.
	lina Herbst
	aphrodite Feld.
	dilis Bdv.
	marion G. & S.
	acutipennis Btl.
limnorina Feld.	—
dissimulata d'Almeida	—
theugenis Dbl.	—
melite L.	*flavia* Feld.
	melite L.
	cornelia Feld.
	albania Bates

It will be seen that *licinia* now includes eight forms treated as sub-specifically distinct by Talbot (1932–35). The ground-colour is a pale yellowish-cream in all. The species gives a striking flavone reaction with ammonia. On extracting with ethyl acetate, 3 specimens supply a sufficient quantity of the pigment to produce a just detectable effect. I have placed *acutipennis* next to *marion*, from which it is separated in *Lepidopterorum Catalogus*, as these two subspecies are evidently closely allied, and Mr. G. Talbot informs me that he is in agreement with this alteration.

E. limnorina is a very distinct species. Its pale ground-colour allows the immediate demonstration of its anthoxanthins by means of the ammonia test.

E. dissimulata is unknown to me.

E. theugenis is a somewhat uncommon species. The ground-colour is usually deep yellow, but a single specimen in the British Museum was pale enough for the demonstration of its anthoxanthins by means of the ammonia test. However, their presence can always be proved by extraction with ethyl acetate, 3 specimens being sufficient for this purpose.

E. melite has a ground-colour ranging from deep yellow, sometimes suffused with orange, to ivory. Anthoxanthins are easily demonstrated by ammonia in the whitish form *alba* Röb., and in the palest of subspecies *albania*. They can also be detected in the deep yellow forms by extraction with ethyl acetate. Three specimens produce a definite effect, so that the total quantity appears to be approximately the same as in the other species of the genus.

Röber (1909) mentions, and figures, *citrinella* Feld. which he described as " a species scarcely differing from *melite*." Its ground-colour is of a sulphur shade. Talbot (1932–35) regards the name as a synonym either of *flavia* Feld. or of *albania* Bates. The latter comprises forms of *melite* generally paler than the description of *citrinella* indicates; while the former agrees very well with the description of *citrinella*. However, *flavia* (Feld., 1861, *Wien. ent. Monats.* 5 : 76) has page priority over *citrinella* (*ibid.* : 77) and should be used for this form. There is no reason to think it specifically distinct from *melite*.

As already pointed out (p. 72), *Eronia cleodora* and *Gandaca harina* are the only Pierid species possessing anthoxanthins as wing pigments outside the genera *Leptidea*, *Pseudopieris*, and *Enantia*, in which they are invariably found. It may reasonably be supposed therefore that they merely represent very rare exceptions. It is just possible, however, that the latter species may be in rather a different position from the former in this respect. *Eronia* is quite closely allied to the neighbouring genera, while the amount of anthoxanthin present in the wings of *E. cleodora* is minute, unlike the genera of which this type of pigment is characteristic. However, *Gandaca* is an isolated genus, as indicated by its venation (Talbot, 1939). It was formerly included in the genus *Eurema*, some species of which it closely resembles. But this similarity is purely superficial. Brigadier W. H. Evans informs me that he has long realised that it is entirely distinct from them : a conclusion first suggested by its very different habits. This is now supported by the chemical evidence presented by the present work.

It is just possible therefore that the possession by *Gandaca harina* of abundant anthoxanthins indicates some affinity with the DISMORPHIINAE. If so, its nearest ally among the latter subfamily is presumably *Leptidea*, the only Asiatic (Palaearctic) genus of DISMORPHIINAE, for *G. harina* inhabits the Oriental Region (ranging from north-eastern India and Burma to New Guinea). Its food-plant is not known, but it is probably one of the Leguminosae, as is characteristic of the COLIADINAE to which it belongs. I can find no information on the food-plants of the neotropical DISMORPHIINAE; but *Leptidea* also feeds on Leguminosae, whereas the TERACOLINAE and PIERINAE are predominantly feeders on Capparidaceae and Cruciferae respectively.

It might be possible, therefore, to regard *Gandaca* as the most primitive of the COLIADINAE and to remove this genus to the end of the subfamily, allying it distantly with the genus *Leptidea* in the DISMORPHIINAE. Mr. G. Talbot informs me that he sees no objection to such an alteration. This would place the DISMORPHIINAE closer to the COLIADINAE than to any other group. One might consequently arrange the subfamilies of the PIERIDAE in the following sequence : 1 PIERINAE, 2 TERACOLINAE, 3 COLIADINAE (ending with *Gandaca*), 4 DISMORPHIINAE (beginning with *Leptidea*, see p. 73), 5 PSEUDOPONTIINAE whose position is arbitrary. The TERACOLINAE are very close to the COLIADINAE, indeed Talbot (1939) considers that they are not even separable from them. However, it may be a convenience to retain them as distinct, since they differ from the COLIADINAE (as from the PIERINAE) in their food-plants, which principally belong to the Capparidaceae. Though I should not at all wish to

stress the suggestion that *Gandaca* is other than an exception in its possession of abundant anthoxanthins, the possibility just considered should at least be borne in mind in considering the interrelationships of the family.

The application of chemical methods to the classification of the PIERIDAE has been of use in several ways. It has confirmed the relationship of the Palaearctic "Wood Whites" (*Leptidea*) with the Central and South American DISMORPHIINAE. It has provided a natural order for the genera of this subfamily, previously arranged almost at random. It has distinguished, upon rather clear evidence, two genera (*Enantia* and *Dismorphia*) which had been wrongly combined. It has corrected an error in the classification of a species (*Dismorphia thermesia*); and it has confirmed the opinion that *Gandaca* is an isolated genus not closely allied to *Eurema*. Furthermore, it has suggested at least possible affinities between subfamilies hitherto quite arbitrarily grouped. These results might not have been attained by other means.

4. Anthoxanthins in the family PAPILIONIDAE.

The bearing of chemistry on classification in the PAPILIONIDAE cannot be studied without a detailed consideration of two important types of red pigment (Ford, 1940). Consequently, little but the data on the occurrence of anthoxanthins in the family will be presented now. Except for a few points which can be discussed at once, its significance will be reserved for treatment in the next paper of this series, which is to deal with the red pigments in question. Thus it has seemed well to place the PIERIDAE first in this article as a family in which the work on anthoxanthins could be carried to completion, and to deal with the mere distribution of these pigments in the PAPILIONIDAE afterwards.

The classification of the PAPILIONIDAE adopted here is that used in the appropriate sections of the *Macrolepidoptera of the World* (Seitz, 1907; Jordan, 1907, 1908–9; Aurivillius, 1908, 1910). The species are therefore grouped according to faunistic regions. The following minor alterations are, however, made : (1) The three sections into which the genus *Papilio* is divided in that work are treated as separate genera here, following Talbot (1939). (2) Prior names are substituted for two of these, and for other genera where necessary. (3) The "Aristolochia Swallowtails" (the "Pharmacophagus Section" of the *Macrolepidoptera of the World*) are divided into two genera *Troides* and *Polydorus* (see Talbot, *loc. cit.*) No changes other than these have been made in the arrangement of the *Macrolepidoptera of the World*.

Talbot (1939) divides the "Fluted Swallowtails" into two genera : *Chilasa* and *Papilio*. This procedure, which is not adopted here, will be discussed in the next paper of this series, in which it is hoped to review the classification of the PAPILIONIDAE in detail.

The most recent revision of the PAPILIONIDAE is that of Talbot (1939), but it is restricted to British India. Two classifications of the family covering its entire range have appeared during the present century, those of the *Macrolepidoptera of the World* itself, and of Bryk (1923–30). However, the latter does not even distinguish the "Kite Swallowtails" (*Graphium*), nor does it divide the species into the numerous groups adopted by Jordan (1907, 1908–9) and Aurivillius (1908, 1910). Not only are these convenient, but there is good evidence to show that some at least of them form natural assemblages. Consequently, with the adjustments already noted, the arrangement of the *Macrolepidoptera of the World* will be followed strictly for the present.

The four genera into which the single genus *Papilio* of the latter work is now divided are : 1. *Troides* Hb., 1819 (= *Ornithoptera* Bdv., 1832); 2. *Polydorus*

Swainson, 1833. (These two genera comprise the " Aristolochia Swallowtails," i.e., *Pharmacophagus* Haase, 1892.) 3. *Papilio* L., the " Fluted Swallowtails "; 4. *Graphium* Scopoli 1777 (= *Cosmodesmus* Haase, 1892), the " Kite Swallowtails."

The first two of these genera are, of course, much the most closely allied. The above order is that in which the corresponding groups are placed by Jordan (1907, 1908–9), but Aurivillius (1908, 1910) interchanges the Aristolochia and the Fluted Swallowtails. It will be shown in the next paper of this series that the latter arrangement is probably to be preferred.

I have examined 116 species of *Papilio* (s.s.), drawn from the entire range of the genus, without finding anthoxanthins in any of them. Since this large sample contains no exceptions, the list of those tested is omitted, in order to save excessive tabulation. Similarly, it appears unnecessary to list the species of *Troides* examined, since these comprise the majority of the genus (19 out of approximately 27) and none possessing anthoxanthins was found. However, *Polydorus* and *Graphium* both contain exceptions which make it essential that the data upon these genera should be supplied in full. They are given in Tables 6–8. A summary of the results is provided in Table 9.

It will be seen that *Papilio* and *Troides* are invariably without anthoxanthins. These pigments are generally absent from *Polydorus* also. However, when present, their occurrence in the latter genus is not uniform, for they are restricted to the New World species, among which they are predominantly found in the Aeneas group. The relation between the distribution of these pigments and accepted classification is further indicated by the fact that the only species, two in number, in which I have found anthoxanthins outside the Aeneas group belong to groups placed on either side of it.

When anthoxanthins occur in *Polydorus* species, they do so in a very different way from that of all other genera of the PAPILIONIDAE. (1) The quantity of these pigments is much smaller, so that they are far more difficult to detect, whereas in most of the other instances they are abundant and easily demonstrated. (2) They are often present in some forms only of each species. This is entirely different from anything encountered elsewhere, except in *Graphium ariarathes* Esp. and *G. lysithous* Hb. (p. 81). In consequence of these two considerations, the existence of anthoxanthins in the genus *Polydorus* is very easily overlooked. In writing on this subject on a previous occasion (Ford, 1938a) I was myself completely deceived. For at that time I had an insufficient acquaintance with the American species, among which alone are traces of these pigments to be found—usually in certain forms only.

If anthoxanthins occur in any form of a species, it is listed as possessing them in Tables 6 and 9. It should be noticed that this tends to exaggerate the importance of these pigments in *Polydorus*. Their distribution in the species of this genus is examined more fully in Table 7. I am, of course, concerned only with those forms possessing white or yellow pigments. These colours are more frequently absent from the males than from the females. However, when they occur in the former sex, no sexual difference in the distribution of anthoxanthins is to be detected. Consequently, the two sexes are not separately distinguished in Table 7. In general, it may be said that anthoxanthins are absent in pure white spots but present in those of a cream or yellowish colour. It is possible that these pigments exist in some of the other species of the Aeneas group in which I have not studied the appropriate forms. Thus I would attach no significance to the distribution within this group of the species recorded as possessing them.

TABLE 6.

Species of the genus *Polydorus* tested for anthoxanthins. Total : 62. These pigments are absent in all but 13, marked *.

Region	Group	Species
Indo-Australian	Nox	*priapus* Bdv., *hageni* Rogenh., *varuna* White, *zaleucus* Hew., *nox* Sw.
	Latreillei	*latreillei* Don., *adamsoni* Sm., *nevilli* Wood-Mas., *philoxenus* Gray, *dasarada* Moore
	Coon	*neptunus* Guér., *coon* F., *rhodifer* Btl.
	Hector	*hector* L., *jophon* Gray, *pandiyana* Moore, *oreon* Doh., *liris* Godt., *polyphontes* Bdv., *polydorus* L., *aristolochiae* F., *annae* Feld., *phegeus* Hopff.
African	Antenor	*antenor* Drury
American	Ascanius	*ascanius* Cr., *agavus* Drury,* *proneus* Hb., *chamissonia* Esch., *phalaecus* Hew.
	Aeneas	*triopas* Godt., *chabrias* Hew., *coelus* Bdv., *steinbachi* Roths., *klagesi* Ehrm., *aeneas* L.,* *dardanus* F.,* *sesostris* Cr.,* *childrenae* Gray,* *erlaces* Gray, *cutorina* Stgr.,* *vertumnus* Cr.,* *lycimenes* Bdv.,* *erithalion* Bdv.,* *iphidamas* F.,* *anchises* L.,* *nephalion* Godt.*
	Lysander	*aglaope* Gray, *lysander* Cr., *echemon* Hb., *neophilus* Hb., *zacynthus* F., *arcas* Cr.,* *timias* Gray.
	Polydamas	*philenor* L., *devilliers* Godt., *streckerianus* Honr., *archidamas* Bdv., *polydamas* L., *madyes* Dbl., *belus* Cr., *laodamas* Fldr., *crassus* Cr.

TABLE 7.

The distribution of anthoxanthins among the forms of the *Polydorus* species possessing them (see Table 6). Only forms with white or yellow markings are considered.

Species	Forms	
	Anthoxanthins	
	absent	present
agavus Drury	—	all
aeneas L.	white-spotted forms (e.g. *marcius* Hb.)	yellow-spotted forms (e.g. *bolivar* Hew.)
dardanus F.	—	all
sesostris Cr.	white-spotted forms	yellow-spotted forms
childrenae Gray	—	all
cutorina Stgr.	—	all
vertumnus Cr.	white-spotted forms (e.g. *vuracares* R. & J.)	yellow-spotted forms (e.g. *autumnus* Stgr.)
lycimenes Bdv.	most forms (e.g. *paralius* R. & J.)	*erythrus* R. & J.
erithalion Bdv.	—	all
iphidamas F.	most forms (e.g. *elatos* R. & J.)	*iphidamas* F.
anchises L.	most forms	*osiris* Feld.
nephalion Godt.	—	all
arcas Cr.	—	all

TABLE 8.

Species of the genus *Graphium* tested for anthoxanthins. Total : 92. All possess these pigments except 10, marked *.

Region	Group	Species
Palaearctic and Indo-Australian	Antiphates	*eurous* Leech, *glycerion* Gray, *podalirius* L.,* *alebion* Gray, *agetes* Westw., *stratiotes* Sm., *leosthenes* Dbl., *nomius* Esp., *aristeus* Cr., *rhesus* Bdv., *dorcus* Dehaan, *androcles* Bdv., *antiphates* Cr., *epaminondas* Ob., *euphrates* Fldr.
	Payeni	*gyas* Westw.*
	Codrus	*macleayanus* Leach, *weiskei* Ribbe, *codrus* Cr.
	Eurypylus	*mendana* G. & S., *eurypylus* L., *meyeri* Hopff., *bathycles* Zink., *leechi* Roths., *agamemnon* L.
	Macareus	*macareus* Godt., *xenocles* Dbl., *leucothoe* Westw., *delesserti* Guér., *megarus* Westw., *stratocles* Fldr., *deucalion* Bdv., *thule* Wall., *idaeoides* Hew.,* *encelades* Hew.
African	Pylades	*endochus* Bdv., *pylades* F., *morania* Angas
	Tyndaraeus	*cyrnus* Bdv.
	Leonidas	*leonidas* F., *levassori* Ob., *hachei* Dew., *moebii* Suff., *auriger* Btl., *odin* Strand, *ucalegon* Hew., *agamedes* Westw., *adamastor* Bdv., *almansor* Honr., *philonoe* Ward.
	Policenes	*evombar* Bdv., *antheus* Cr., *policenes* Cr., *polistratus* Sm., *junodi* Trim., *porthaon* Hew.
	Kirbyi	*kirbyi* Hew.
American	Lysithous	*pausanias* Hew., *protodamas* Godt., *phaon* Bdv., *euryleon* Hew., *harmodius* Dbl., *trapeza* R. & J., *xynias* Hew., *ariarathes* Esp., *ilius* F., *branchus* Dbl., *lysithous* Hbn., *asius* F.*
	Marcellus	*marcellus* Cr., *celadon* Luc.,* *zonaria* Btl.,* *philolaus* Bdv.,* *arcesilaus* Luc.,* *epidaus* Dbl.,* *bellerophon* Dalm.
	Protesilaus	*agesilaus* Guér.,* *glaucolaus* Bates, *molops* R. & J., *protesilaus* L., *stenodesmus* R. & J., *telesilaus* Fldr.
	Thyastes	*dioxippus* Hew., *lacandones* Bates, *leucaspis* Bates
	Dolicaon	*serville* Godt., *columbus* Koll., *orabilis* Btl., *salvini* Bates, *callias* R. & J., *dolicaon* Cr., *iphitas* Hbn.

It will be seen from Tables 8 and 9 that, unlike the three preceding genera, *Graphium* contains predominantly species which possess anthoxanthins, generally in abundance. However, they are not always easy to detect in the Macareus group, in which the quantity is small and the scaling of the pale areas often defective. It may be added that *G. auriger* Btl. and *G. odin* Strand provide an example of two closely allied species in which the amount of anthoxanthin differs considerably, being much smaller in the latter.

I have found two *Graphium* species in which anthoxanthins exist in some forms but not in others. (1) They occur in most forms of *G. ariarathes* Esp. (e.g. *luctra* R. & J.), but are absent in *G. a. evagoras* Gray. (2) They are usually present, in very small quantity, in the forms of *G. lysithous* Hbn., but not in *G. l. lysithous* itself. It is a highly remarkable fact that there should exist (here and in *Polydorus*) species in some forms of which anthoxanthins contribute to the white and yellow pigments while in others they do not. It would be of much interest to obtain information on the genetics of this situation.

I have already commented on its significance in respect of *G. ariarathes* (Ford, 1938a, 1940).

According to Cockayne (1924), the only species of *Graphium* (*Cosmodesmus*) which show any considerable fluorescence in ultra-violet light are *G. zonaria* Btl. and *G. philolaus* Bdv. This observation attracted my special attention, since these chance to be two of the exceptional *Graphium* species from which anthoxanthins are absent. In all, these exceptions amount only to 10 out of 92 (Tables 8 and 9). I therefore examined the remainder of them under ultra-violet light. I found that while the fluorescence of the other eight is not always so brilliant as in the species mentioned by Cockayne, it is none the less definite. *Graphium asius* F., *arcesilaus* Luc., *epidaus* Dbl., and *G. agesilaus* Guér., fluoresce brightly, *G. gyas* Westw. and *idaeoides* Hew. do so to a somewhat smaller extent, while the fluorescence of *G. podalirius* L. and *G. lysithous* [5] is slight but detectable. In *celadon* Luc. the scales are degenerate over the pale areas. However, a single pale spot, distal to the red mark on the upperside of the hind-wings, is normally scaled. This shows no evidence of anthoxanthin pigment, and is fluorescent in ultra-violet light. Anyone who compares simultaneously the behaviour under ultra-violet light of one of these with that of such species as *marcellus* Cr. or *bellerophon* Dalm., which contain abundant anthoxanthins, will be in no doubt of the fluorescence of the former.

The members of the Protesilaus group are exceedingly similar in appearance. The absence of anthoxanthins from *G. agesilaus* Guér. on the one hand, and its fluorescence in ultra-violet light on the other, are in equal and surprising contrast with its close allies. The same is true of *G. marcellus* Cr. and *G. bellerophon* Dalm., both being non-fluorescent in ultra-violet light and possessing anthoxanthins, when compared with the other members of the Marcellus group.

The relation between the distribution of anthoxanthin pigments and the present classification is indicated by the fact that 7 out of the 10 exceptional species of *Graphium* belong to the Marcellus group or to its close allies. Indeed it is noteworthy that the single species of the Lysithous group (*G. asius* F.), and the single species of the Protesilaus group (*G. agesilaus* Guér.), which are without anthoxanthins should have been placed respectively at the end and the beginning of their groups (Table 8) : that is, next to the Marcellus group.

Graphium idaeoides Hew., which mimics *Idea leuconoë*, is very distinct from its allies and possesses no anthoxanthin pigment. It should certainly be moved to the end of the Macareus group.

In general, it may be said that anthoxanthins contribute to the white and yellow colours of the *Graphium* species, save in a few exceptions in which they appear to be replaced by pale yellow pigments fluorescent in ultra-violet light.

The four genera already discussed comprise the true " Swallowtails." In the *Macrolepidoptera of the World* they were combined in the single immense genus *Papilio*. In that work they are followed by twelve other genera, which complete the family PAPILIONIDAE. With the exception of *Parnassius*, these are all small, containing three species or fewer. Table 9 shows the distribution of anthoxanthins within these remaining genera [6] (as well as within the true Swallowtails). Their order is that followed in the *Macrolepidoptera of the*

[5] In this species anthoxanthins are present in small quantity only, or are absent (p. 81).

[6] In several instances, prior generic names must be substituted for those used in the *Macrolepidoptera of the World*, as follows : *Cressida* Sw., 1833 (= *Eurycus* Bdv., 1836); *Lamproptera* Gray, 1832 (= *Leptocircus* Swainson, 1833); *Zerynthia* Ochsenh., 1816 (= *Thais* F., 1807 ; preoccupied for a Molluscan genus, *teste* Bryk, 1922).

TABLE 9.

The occurrence of anthoxanthins in the genera and species of the family PAPILIONIDAE.
(* = approximate only.)

Genus	Species			
	Anthoxanthins		Total examined	Total in genus
	present	absent		
Papilio	—	116	116	?
Troides	—	19	19	27 *
Polydorus				
(Old World)	—	(24)	(24)	?
(New World)	(13)	(25)	(38)	?
Total	13	49	62	?
Graphium	82	10	92	?
Euryades	—	2	2	2
Baronia	—	[1]	1	1
Cressida	—	1	1	1
Lamproptera	2	—	2	2
Teinopalpus	—	1	1	1
Luehdorfia	—	1	1	1
Bhutanitis	—	2	2	3
Sericinus	—	1	1	1
Zerynthia	—	3	3	3
Hypermnestra	—	1	1	1
Doritis	—	1	1	1
Parnassius	29	—	29	29 *

World, as far as can be determined by combining the accounts of the different faunistic regions. In the next paper of this series additional information on the chemistry of these genera can be combined with the data here provided. It will then be possible to relate these additional genera to the various groups of the true Swallowtails to which they are allied. The order now followed will therefore be greatly altered, resulting, it is hoped, in a more natural classification of the PAPILIONIDAE.

It will only be necessary here to comment on a few special points. Owing to the great rarity of the single species of *Baronia* (*B. brevicornis* Salvin), it has not been possible to sacrifice specimens for pigment extraction. The yellow areas are of a deep shade which would make the ammonia test for anthoxanthins effective only if the amount present were considerable. No alteration can be detected on fuming, and general considerations suggest that this genus is related to those Aristolochia butterflies in which anthoxanthins are absent. The point can of course be established when sufficient material becomes available for pigment extraction from, say, 6 specimens.

The two species of *Bhutanitis* Atkinson 1873 (= *Armandia* Blanch., 1871 praeocc.) which have been studied are of course *thaidina* Blanch. and *lidderdalei* Atkinson. Very few specimens of *mansfieldi* Riley are known.

Since I have examined approximately the whole of the *Parnassius* species [7] and have encountered no exceptions, it appears unnecessary to list them. The presence of anthoxanthin pigment is clearly a fundamental character of the genus.

[7] Some doubt exists as to the specific status of certain forms.

On fuming all species of *Parnassius* with ammonia, several seconds elapse before any reaction is obtained; the resulting yellow coloration then remains for some minutes after exposure. I have never encountered such a delay elsewhere. It seems due to the heavy chitinisation of the scales, rather than to the quality of the anthoxanthins themselves. This is strongly indicated by the fact that a similar delay occurs in the reaction of the quite unrelated red pigment of this genus. It is of the type converted to yellow by an acid and subsequently reconvertible to red by ammonia (see Ford, 1937, 1940). On extracting with ethyl acetate, 6 specimens of *P. apollo* L. supply sufficient anthoxanthin pigment to produce a positive reaction, while 3 do not. The amount available is therefore less than in the Pierine genus *Enantia* (p. 76), though the latter are much smaller butterflies. The deep colour obtained on fuming with ammonia suggests that this is due to the thin scaling of *Parnassius*, and that the amount of pigment within each scale is considerable.

In *Lamproptera* (= *Leptocircus*) the presence of anthoxanthins is demonstrated easily in *L. curius* F., but with some difficulty in *L. meges* Zink. The oblique band crossing the wings in the former species is coloured white by a pigment containing anthoxanthins enclosed within normal scales. In the latter, this band is scaleless and its colour is produced by a pale green inter-laminar pigment. The only region available for anthoxanthins is the narrow white outer edge of the hind-wings and tails, and here they can be detected.

I have already pointed out (Ford, 1938a) that the presence of anthoxanthins in *Lamproptera* (*Leptocircus*) supports the suggestion of Jordan (1908–9 : 107) that this genus is derived from *Graphium* (*Cosmodesmus*). At that time I had not discovered traces of anthoxanthin pigment in some of the American species of *Polydorus*, but I see no reason to modify my previous view on that account. *Graphium* remains the only genus of true " Swallowtails " of which anthoxanthin pigments are characteristic. *Lamproptera* is an Oriental genus, while anthoxanthins are absent from the Old World species of *Polydorus*, as they are throughout *Troides* and *Papilio* s.s. Consequently, the existence of anthoxanthins in *Lamproptera* provides strong support for its affinity with *Graphium*, a conclusion originally reached on quite other grounds.

5. The occurrence of anthoxanthins in other families.

As already explained (p. 69), I have made a brief survey of the distribution of anthoxanthins in the remaining families of butterflies and in a selection of the families of moths, so that those working on any of them may know if the occurrence of these pigments provided them with an additional character for taxonomic study. The results are given in Tables 10 and 11. These list the total number of genera examined possessing white or yellowish colours, and the number of these to which anthoxanthins either do or do not contribute. The genera chosen have been selected as widely as possible through each family. In order to save very extensive tabulations, only those are given in which these pigments have been found. Representative species only have been selected within each, but a considerable number have been studied within all the larger genera. Their behaviour has been consistent within each genus except where stated to the contrary.

It has been my aim to show in which families anthoxanthins exist. However, I have worked out their dispersal in the SATYRIDAE in a little more detail, in order to demonstrate that the occurrence of these pigments can be made to give information of some value on classification even when investigated less extensively than has been done in the PIERIDAE and PAPILIONIDAE.

The distribution of anthoxanthins within the various families of butterflies is given in Table 10. The nomenclature is based on that of the *Macrolepidoptera of the World*. The PAPILIONIDAE and PIERIDAE, already discussed, are added here for the sake of completeness in comparison. It will be necessary to mention only a few points of importance in regard to each.

In the DANAIDAE the number both of genera and species is remarkably small considering the importance of the family. I have tested several species

TABLE 10.

The occurrence of genera possessing anthoxanthins within the families of the Rhopalocera. Subfamilies are added when of special importance. In the PAPILIONIDAE and the PIERIDAE every existing genus has been tested. (* = these contain a single genus only).[8]

Family	Genera			
	Anthoxanthins		Total examined	Per cent. possessing anthoxanthins
	present	absent		
PAPILIONIDAE	4	12	16	25
PIERIDAE	5	63	68	7
DANAIDAE				
(ITHOMIINAE) . . .	—	(8)	(8)	—
(DANAINAE) . . .	—	(11)	(11)	—
Total	—	19	19	—
SATYRIDAE . . .	7	39	46	15
AMATHUSIIDAE . . .	—	6	6	—
BRASSOLIDAE . . .	—	4	4	—
MORPHIDAE . . .	—	1	1 *	—
NYMPHALIDAE				
(ACRAEINAE) . . .	—	(3)	(3)	—
(HELICONIINAE) . . .	—	(1)	(1)	—
(NYMPHALINAE) . . .	—	(88)	(88)	—
Total	—	92	92	—
ERYCINIDAE				
(LIBYTHEINAE) . . .	—	(1)	(1)*	—
(RIODININAE) . . .	(3)	(21)	(25)	(12)
Total	3	22	26	12
LYCAENIDAE . . .	6	19	25	24
HESPERIIDAE . . .	10	15	25	40

within all the larger genera (*Danaus, Amauris, Euploea*), making sure that they are widely separated within them.

I have examined the SATYRIDAE in some detail. The seven genera possessing anthoxanthins (out of 46 tested) are as follows: *Arge* (12 species tested, present in all), *Satyrus* (present in *circe* F., *briseis* L., *prieuri* Pierret, *anthe* Ochs, *sybillina* Ob.; absent in *hermione* L., *alcyone* Schiff.), *Aulocera* (*brahminus* Blanch., *swaha* Koll., *padma* Koll., *saraswati* Koll.), *Oeneis* (present in *aello* Hbn., *tarpeia* Pall., absent in 6 other species), *Physcaeneura* (*leda* Gerst.), *Coenonympha* (19 species tested, present in all), *Oressinoma* (*typhla* D. & H.). In the first six of these genera the anthoxanthins are abundant; in the last they are present in small quantity only.

[8] The arrangement of the *Macrolepidoptera of the World* is followed in this table. However, the name ERYCINIDAE is now replaced by RIODINIDAE, and the Libytheini are included in the NYMPHALIDAE.

Seitz (1908) placed *Arge, Oeneis*, and *Satyrus* consecutively, while Fruhstorfer (1911) reversed the order of the last two. Seitz actually included the *Aulocera* species in *Satyrus*, while Fruhstorfer separated them by two small genera, *Orinoma* (without anthoxanthins) and *Rhaphicera* (not examined). Chemical evidence suggests that *Aulocera* and *Satyrus* should at least be placed next to each other. Aurivillius (1911) separated *Physcaeneura* from *Satyrus* (called by him *Pararge*) by four small genera: *Leptoneura, Meneris*, and *Aphysoneura* (all without anthoxanthins), and *Coenyra* (not tested). This separation is probably an error.

Coenonympha is far removed from the genera just discussed; but Weymer (1910, 1911, 1912) separated *Oressinoma* from it only by two monospecific genera, *Paramecera* (without anthoxanthins) and *Satyrodes* (not examined). *Coenonympha* and *Oressinoma* should perhaps be brought together.

TABLE 11.

The occurrence of genera possessing anthoxanthins within certain families of the Heterocera.

Family	Genus			
	Anthoxanthins		Total examined	Per cent. possessing anthoxanthins
	present	absent		
SPHINGIDAE	1	11	12	8
NOTODONTIDAE	—	5	5	—
GEOMETRIDAE	—	50	50	—
SATURNIIDAE	—	7	7	—
URANIIDAE	—	5	5	—
SYNTOMIDAE	—	4	4	—
ARCTIIDAE	—	14	14	—
AGARISTIDAE	5	6	11	45
AGROTIDAE	1	52	53	2
LYMANTRIIDAE	—	13	13	—
HYPSIDAE	—	9	9	—
ZYGAENIDAE	3	5	8	38
CASTNIIDAE	—	1	1	—

It will thus be seen that two distinct groups of genera in the SATYRIDAE possess anthoxanthins. These centre round *Arge* and *Coenonympha*. Consequently the distribution of these pigments is rather closely related to the present classification of the family.

The AMATHUSIIDAE and BRASSOLIDAE contain only 15 and 8 genera respectively. In the latter family is a large genus *Caligo*, of which I have examined four species. The MORPHIDAE comprise the single genus *Morpho*, within which I have also examined four species.

The subfamily ACRAEINAE of the NYMPHALIDAE includes the very large genus *Acraea*; here I have tested 16 species. Within the HELICONIINAE I have examined 8 species of *Heliconius*. In the vast subfamily NYMPHALINAE I have examined several species within the larger of the 88 genera studied.

It appears, therefore, that anthoxanthins are absent from the great family NYMPHALIDAE. I have based this conclusion upon the study of a large number of the genera because it is always difficult to establish a negative proposition.

However, these pigments are found in the three families remaining to be mentioned. I have accordingly examined a sample of 25 genera scattered as widely as possible within each, in order to give a rough indication of frequency. In the ERYCINIDAE this sample is in addition to the very distinct genus *Libythea*.

The 3 genera of the ERYCINIDAE in which I have found anthoxanthins are *Helicopis*, *Calydna*, and *Anteros*. I have found these pigments in the following genera of LYCAENIDAE : *Phlyaria*, *Castalius* (in some species they are present, in others absent), *Lycaenopsis*, *Thysonotis*, *Talicada*, *Nacaduba*.

Table 10 shows that anthoxanthins are especially common in the HESPERIIDAE. I have found them in the following genera : *Hesperia*, *Hyalothyrus*, *Pellicia*, *Udaspes*, *Heliopetes*, *Milanion*, *Baracus*, *Netrobalane*, *Gomalia*, *Abantis*. In the last genus they are absent from *A. venosa* Trim., *A. paradisea* Btl., *A. zambesiaca* Westw., *A. bismarcki* Karsch., and present in *A. tettensis* Hopff., and *A. levebu* Wallengr. It may be questioned whether these two species should not be separated from *Abantis* (not necessarily into the same genus). This plan has already been advanced in favour of *levebu*, which is sometimes given a genus *Leucochitonea* Wallengr. It appears, therefore, that anthoxanthins are widely distributed in the HESPERIIDAE, a fortunate circumstance in a family of notorious taxonomic difficulty, where an additional character for study may be welcome.

Table 11 shows the distribution of anthoxanthins within a number of families of the Heterocera. The genera in which I have found them are as follows : SPHINGIDAE, the single American genus *Euproserpinus* (*E. phaeton* Gr. & Rob., a day-flying form). In the AGARISTIDAE, when present, the quantity is small. They occur in *Rothia*, *Charilina*, *Aegocera*, *Paraegocera*, and *Hespagarista*.

It is clear that anthoxanthins must be very rare in the great family AGROTIDAE (NOCTUIDAE). I have found them in a single genus only (out of 53), namely *Apsarasa* (*A. radians* Westw.). It belongs to the subfamily ACRONICTINAE, and Mr. W. H. T. Tams kindly informs me that he does not regard it as in any way exceptional. In the ZYGAENIDAE I have detected these pigments in *Chalcosia* (3 species tested, present in all), *Cyclosia* (present in *C. papilionaris* Drury and *C. pieroides* Walker, absent in *C. macularia* Guér. and *C. pieridoides* H.-S.) and *Caffricola*.

It seems that anthoxanthins are absent from, or very rare in, the vast family GEOMETRIDAE, since I have tested a sample of 50 widely scattered genera without detecting them. Yet white pigments are exceedingly common among the species.

In general, a comparison of Tables 10 and 11 suggests that anthoxanthins are more frequent in the butterflies than in the moths. They occur in 7 out of 11 families in the former, and in 4 out of 13 in the latter; that is, twice as commonly in the butterflies.[9] A peculiar circumstance also is their apparent association with day-flying forms since, out of 10 genera of moths in which I have found them, only 1 (*Apsarasa*) is probably nocturnal.

It would be a delightful task to study the distribution of these pigments relative to classification in the remaining families of butterflies, and in the moths, in which they are known to occur. I must leave this, as I hope, for others, since I have now devoted as much time to this subject as I can spare.

[9] An almost equal disparity is obtained when the number of genera tested is considered. The result is 38 out of 328 in the butterflies and 10 out of 192 in the moths. Thus again anthoxanthins occur twice as commonly in the former group. However, such estimates are very rough, owing to unequal sampling.

6. Summary.

1. It is proposed to publish a short series of papers on the chemistry of wing-pigments in the Lepidoptera with reference to their bearing on classification. Of these the present work, devoted to the anthoxanthins, is the first.

2. Anthoxanthins are plant pigments responsible for a series of colours from white to yellow. In general, they are very rare in animals, which cannot manufacture them but derive them from their food.

3. So far, they have been reported in the Lepidoptera in one or two instances only, for the white and yellow pigments of this Order are usually of a different nature.

4. It is here shown that, though uncommon, anthoxanthins are widely spread in the Lepidoptera. When they occur, they are generally not alone responsible for white and yellow colours, other pigments being present in addition.

5. Their existence has been demonstrated by the tests described on p. 68.

6. The distribution of anthoxanthins has been studied in detail in the PIERIDAE and the PAPILIONIDAE. A less thorough survey has been made of their occurrence in the other families of butterflies, and in a number of families of moths, so that taxonomists will know where they are available for use.

7. Anthoxanthins are very rare in the PIERIDAE, but are found in the aberrant central and South American family DISMORPHIINAE (in the genus *Dismorphia* in 12 out of 50 species tested, and in all three species of *Pseudopieris*).

8. They also occur in all three species of the Palaearctic " Wood Whites " (*Leptidea*), which have been united with the DISMORPHIINAE on structural grounds. Their presence supplies independent evidence for this affinity.

9. The 12 species possessing anthoxanthins in the large genus *Dismorphia* are not distributed at random on the existing classification but (except for the interpolation of *thermesia* Godt.) they are all grouped together.

10. They form a compact assemblage, now to be separated from *Dismorphia* as the genus *Enantia*.

11. The absence of anthoxanthins in *thermesia* Godt. indicated that this species had been misplaced. On further investigation, this conclusion proved to be supported on structural evidence.

12. The distribution of anthoxanthins supplies a natural order for the genera of the DISMORPHIINAE (p. 76).

13. Outside the DISMORPHIINAE, anthoxanthins are almost non-existent in the PIERIDAE, occurring only in 2 out of 233 species tested. In one of these, *Eronia cleodora* Hbn., the amount is so small as to be nearly undetectable. In the other, *Gandaca harina* Horsf., it is large.

14. Chemical evidence, therefore, confirms the view that the mono-specific genus *Gandaca* is an isolated one, not closely related to *Eurema*, with which it was formerly associated.

15. It is possible that the possession by *Gandaca* of abundant anthoxanthins indicates some affinity with *Leptidea* in the DISMORPHIINAE. If so, the COLIADINAE, feeding on Leguminosae, to which *Gandaca* belongs, should be placed next to that family. *Leptidea* also feeds on Leguminosae, though the PIERINAE and TERACOLINAE feed on Cruciferae and Capparidaceae respectively.

16. In the PAPILIONIDAE anthoxanthins are found in 4 genera out of 16.

17. They are present in *Polydorus* in small quantity and in some American species only. Their distribution can be employed to adjust the species to a more natural order.

18. They are found in all the species of *Graphium* tested except 10 (out of 92), in which they appear to be replaced by a pale yellow pigment fluorescent in ultra-violet light. The distribution of the exceptions is related to classification.

19. Anthoxanthins are present in both species of *Lamproptera*, so confirming their suggested affinity with *Graphium*.

20. In a few instances, one form of a species may possess anthoxanthins and another not. The significance of this is discussed.

21. Anthoxanthin pigments are found also throughout *Parnassius*.

22. The distribution of anthoxanthins within the PAPILIONIDAE will be more fully related to classification in a subsequent paper, in which the red pigments can be considered in addition.

23. The distribution of anthoxanthins in other families of butterflies is given in Table 10. This represents a general survey only, except for the SATYRIDAE, which have been studied somewhat more fully.

24. In the latter family, anthoxanthins are found in genera grouped round *Arge* and *Coenonympha* respectively.

25. Table 24 shows the distribution of anthoxanthins in certain families of moths.

26. In general, the occurrence of anthoxanthins within the Lepidoptera supports the present classification of the Order upon evidence wholly distinct from that upon which it had been constructed. It further provides a useful addition to the characters available for taxonomic study, from which results of some value have already been obtained.

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BOOK NOTICE.

French–English Science Dictionary for Students in Agricultural, Biological, and Physical Sciences. By L. DE VRIES. 8vo. London (McGraw-Hill Publishing Co., Ltd.), 1940. Price 24*s.* 6*d.* pp. viii + 546, printed in double column.

This Dictionary has been produced by Prof. De Vries with the collaboration of members of the Graduate Faculty of Iowa State College.

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Many words which are spelled the same in French and English are included in an attempt to assist the reader. It is apparent that the Dictionary has been compiled with the aim of assisting the reader always kept well in mind.

No comprehensive inclusion of names of animals, insects, plants and chemical compounds are attempted owing to limitation of space.

A very useful 12-page list of abbreviations with their English meanings is added to the volume.

A NOTE ON OVIPOSITION PREFERENCES IN *SMERINTHUS POPULI* (L.) (LEPIDOPTERA, SPHINGIDAE)

By J. A. REID, B.Sc., A.R.C.S., F.R.E.S.

THE following is an account of a few very simple experiments made with a single female of the poplar hawk moth, *Smerinthus populi* (L.). It would be exceedingly rash to assume that the results obtained with this specimen are true for the species as a whole, and no such claim is made. It is thought worth while to record the results, because they show that the experimental method employed, though very simple, was nevertheless able to reveal definite oviposition preferences in the insect.

The moth was taken mating on a fence at Gerrards Cross, Buckinghamshire, 28.v.1939. The pair of moths was placed in a tin, and during the night of 28th, 69 eggs were laid. The first experiment was made during the night of 29th. The female moth was placed in a large glass jar about one foot high and eight inches in diameter, closed by a glass lid arranged to allow ventilation. About one inch of damp sand was placed in the bottom of the jar, and single leafy sprigs of willow, sallow and white poplar were stuck into the sand. The following morning the numbers of eggs laid on the different plants were counted. The same method was adopted on subsequent nights, varying the species of plants offered, and the combinations in which they were offered. The following results were obtained :—

					Not on plants	Total
Exp. No. 1. 29 May.	White Poplar	Willow	Sallow			
No. of eggs laid .	15	0	0		10	25
Exp. No. 2. 30 May.	Aspen	Balsam Poplar	Dwarf Sallow			
No. of eggs laid .	12	11	0		38	61
Exp. No. 3. 31 May.	Birch	Willow	Sallow			
No. of eggs laid .	12	9	13		0	34
Exp. No. 4. 1 June.	White Poplar	Balsam Poplar	Aspen	Sallow		
No. of eggs laid .	21	0	1	0	0	22
Exp. No. 5. 2 June.	White Poplar	Balsam Poplar	Aspen	Sallow		
No. of eggs laid .	7	0	6	2	0	15
Exp. No. 6. 3 and 4 June.	White Poplar	Balsam Poplar	Aspen	Sallow		
No. of eggs laid .	9	19	0	3	1	32
Exp. No. 7. 5 June.	White Poplar	Aspen				
No. of eggs laid .	1	0			3	4
					52	193

When these figures are analysed the following facts emerge. In the course of the experiments 193 eggs were laid, and of these 141, or 72·5%, were laid on the plants. In the second experiment 38 eggs were not laid on the plants, and on this occasion the glass lid was replaced by muslin stretched over the top of the jar, on which 21 of the 38 eggs were laid. This suggests that in experiments of this sort, the insect is probably best confined in some container, such as a glass jar, which presents no rough surface.

In experiments 1, 2, 4, 5, and 6 species of poplar and sallow were offered simultaneously (see table below). In these five experiments 101 eggs were laid on species of *Populus* (white, and balsam poplar, and aspen) and only 5 eggs on species of *Salix* (sallow, dwarf sallow and willow). Correcting for the fact that the species of *Populus* were offered 12 times and the species of *Salix* only 6 times, there were 50 eggs on *Populus* spp. to 5 on *Salix* spp.; a ratio of 10 : 1. That is to say, the moth showed a strong preference for ovipositing on species of *Populus* rather than on species of *Salix*.

Table summarising the results of the experiments.

Experiment	White Poplar	Balsam Poplar	Aspen	Total *Populus*	Sallow	Dwarf Sallow	Willow	Total *Salix*	Birch
1	15	—	—	15	0	—	0	0	—
2	—	11	12	23	—	0	—	0	—
3	—	—	—	—	13	—	9	22	12
4	21	0	1	22	0	—	—	0	—
5	7	0	6	13	2	—	—	2	—
6	9	19	0	28	3	—	—	3	—
7	1	—	0	1	—	—	—	—	—
Totals .	53	30	19	102	18	0	9	27	12

If the species of *Populus* are compared individually with those of *Salix* considered together, it may be seen that 52 eggs were laid on white poplar to 5 on *Salix* (Exps. 1, 4, 5, 6) and this does not allow for the fact that the *Salix* were offered five times and the white poplar four. Similarly (Exps. 2, 4, 5, 6) 30 eggs were laid on balsam poplar to 5 on *Salix*, and 19 on aspen to 5 on *Salix* (Exps. 2, 4, 5, 6).

When the three species of poplar are compared, it is fairly obvious that the moth preferred the white poplar; 37 eggs were laid on it to 19 on balsam poplar (Exps. 4, 5, 6), and while 7 eggs were laid on aspen in the presence of white poplar (Exps. 4, 5, 6, 7), 38 eggs were laid on the latter. It is impossible to say from the results of experiments 2, 4, 5, and 6, whether balsam poplar was preferred to aspen, or the reverse; for though 30 eggs were laid on balsam poplar to 19 on aspen, the balsam poplar was refused in two out of the four experiments and only had more eggs than the aspen once, whilst the latter was only refused in one of the four experiments.

Experiment No. 3 was made to see what would happen if plants that were presumed to be unattractive were offered; it will be seen that the three plants, sallow, willow and birch, received approximately equal numbers of eggs.

The moth was found dead on 6 June; it was dissected and the ovaries examined, when 6 fully formed eggs were found in the left ovary and 7 in the right; no semi-mature eggs were seen. The insect laid a total of 263 eggs.

To sum up: when a single female of *Smerinthus populi* (L.) was offered a choice of species of *Salix* and species of *Populus* on which to oviposit, it showed a strong preference for the *Populus*. This agrees with my experience of the species on Gerrards Cross Common, where aspen and sallow grow mixed together; I have only found the larvae of *S. populi* on the aspen; larvae on sallow have always been those of *S. ocellatus* L. Three species of *Populus* were offered, white poplar, balsam poplar and aspen, and of these white poplar was preferred; in addition to receiving the most eggs, the white poplar was the only species that was not refused on any occasion that it was offered.

THE LARVA AND PUPA OF *TACHINUS SUBTERRANEUS* (LINNAEUS) (COLEOPTERA, STAPHYLINIDAE)

By H. E. Hinton, Ph.D., F.R.E.S.

(*Department of Entomology, British Museum (Natural History)*).

With 15 Text-figures.

While collecting during the winter of 1940–41 (1.xii.1940–23.iii.1941) large numbers of larvae and adults of *Tachinus subterraneus* were taken in a compost heap in the grounds of Linton Village College, Cambridgeshire. This heap more or less fills a pit in the ground about ten feet square and three feet deep. During winter it was filled mostly with cabbage leaves. The larvae and adults were found usually near the bottom of the heap among the decayed and partly liquefied cabbage leaves and other plant refuse. Both stages were also collected in other localities near Linton under rotten potatoes, cabbages, etc., on the surface of the ground. The mature larvae were frequently found in small cells in the earth. These cells were usually about six inches from the vertical face of the pit and often two feet below the ground-level. No pupae were seen, but one larva pupated in the laboratory on 27 January, and the adult emerged on 10 February.[1]

T. subterraneus appears to be a mid-winter species. Many days were spent collecting in the same compost heap in the summer of 1940, but not a single adult or larva was found. This species, like the vast majority of the Staphylinidae, is carnivorous, and the adults and larvae appeared to be feeding mainly on dipterous larvae. In captivity they readily attacked and ate each other.

The larvae of seven species of *Tachinus* have been described; two from North America and five from Europe. Four of these occur in England, *T. laticollis* Gravenhorst (1802), *T. humeralis* Gravenhorst (1802), *T. subterraneus* (Linnaeus) (1758), and *T. rufipes* De Geer (1774). The descriptions of *T. laticollis* (Rey, 1892; Xambeu, 1910) and *T. humeralis* (Perris, 1846; Xambeu, 1910) are very poor; and it is only with considerable hesitation that I include them in the key given below. *T. subterraneus* has only been briefly described before now (Rey, 1882; Xambeu, 1910). Schiødte (1872) has given a good description and excellent figures of *T. rufipes*, and I have examined a specimen of the latter in the British Museum and one collected by myself (ii.1941) in a wood near Linton under a decayed piece of *Polyporus squamosus*.

A key to the mature larvae of British *Tachinus*.

1. Length, 6–7 mm. . . . . . . *T. laticollis* Grav., *T. humeralis* Grav.
–. Length, 9–10 mm. . . . . 2.
2. Length, 9 mm. Front of labrum (fig. 7) on each side near middle without teeth. Mandible (fig. 3) with a narrow incision on cutting edge near apical fourth, without a distinct tooth here. Thoracic tergites (fig. 8) with a

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[1] The average laboratory temperature during this time was 68° F. ± 1, with a minimum of 63° F. and a maximum of 72° F.

single long seta on each side near base (the lateral seta of metanotum is more or less opposite basal seta). First eight abdominal tergites (all similar to first, fig. 8) with transverse row of setae on each side consisting of only two long setae; sides of these tergites with a few very fine, short, and inconspicuous setae. Urogomphi (fig. 6) with second segment considerably less than half as long as first. Abdominal sternites (fig. 10) two to eight with a very fine and inconspicuous seta between second and third, counting from middle outwards, of posterior row; ninth sternite with posterior row consisting of two long setae on each side of middle

T. subterraneus (L.)
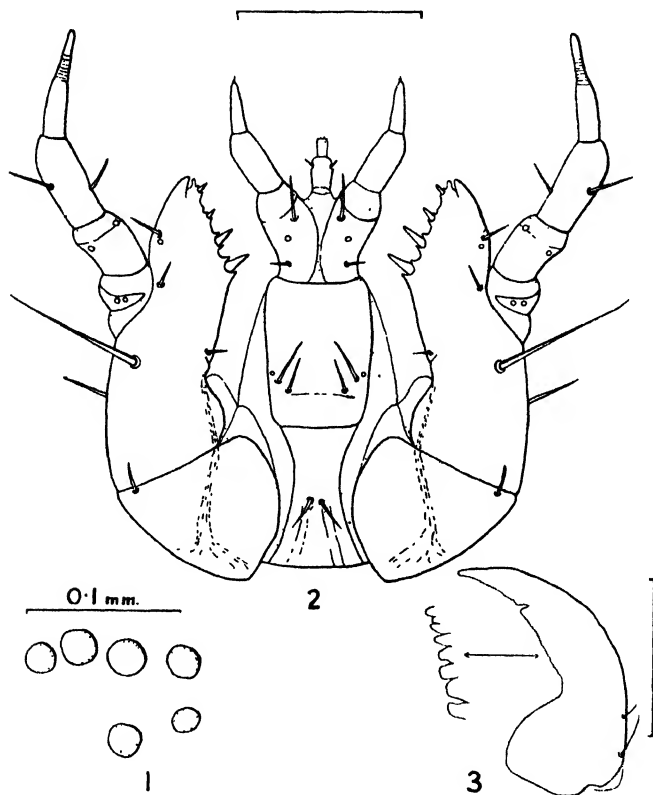
FIGS. 1–3.—Larva of *T. subterraneus* (L.). (1) Ocelli of left side of head. (2) Ventral view of maxilla and labium. (3) Dorsal view of right mandible.

. Length, 10 mm. Front of labrum on each side near middle with a short but conspicuous, stout tooth. Mandible with a moderately large, stout, and distinct tooth on cutting edge near apical fourth. Thoracic tergites with two long setae on each side near base. First eight abdominal tergites with transverse row of setae on each side consisting of three long and one slightly shorter seta; sides of these tergites with three to four stout, moderately long, conspicuous setae. Urogomphi with second segment considerably more than half as long as first (0·65 mm. : 0·82 mm.). Abdominal sternites two to eight with third seta, counting from middle, of posterior row

nearly as long and stout as others of row; ninth sternite with posterior row consisting of three long, stout, lateral and one distinctly finer, shorter, submedian seta on each side . . . .   *T. rufipes* De G.

Description of larva of *T. subterraneus* (L.).

Mature larva: Length, 9 mm.; breadth (across first abdominal segment), 1·2 mm. Body elongate, parallel, and cylindrical to subcylindrical. Cuticle moderately pale brownish-testaceous; pleura and intersegmental membranous areas white to pale yellowish-white. *Head* slightly longer than broad (0·71 mm. : 0·68 mm.); posterior margin broadly, moderately deeply, and arcuately sinuate at middle; coronal suture slightly more than
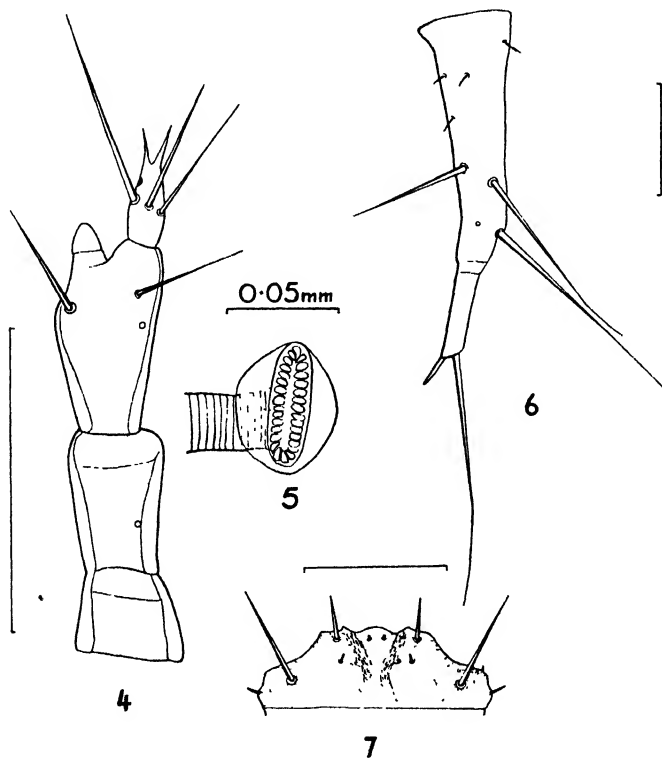
FIGS. 4–7.—Larva of *T. subterraneus* (L.). (4) Dorsal view of right antenna. (5) Spiracle of fifth abdominal segment. (6) Dorsal view of right urogomphus. (7) Dorsal view of labrum.

one-third as long as head (0·24 mm. : 0·71 mm.) and frontal sutures meeting posteriorly in a curve so that middle of caudal margin of frons is evenly and narrowly rounded, not triangular; surface with a long, stout, erect seta on each side slightly posterior to frontal sutures and three shorter, finer setae as follows: one opposite inner base of antenna, one near antero-ventral ocellus, and one near antero-dorsal ocellus; surface also with a few other much shorter and finer setae. Ocelli with six facets on each side as shown in fig. 1. Antenna (fig. 4) as figured. Labrum (fig. 7) without a tooth very near middle on each side; shape and chaetotaxy as figured. Mandible (fig. 2) with cutting edge deeply and narrowly incised near apical fourth and finely but rather unevenly serrate nearly to apex; outer

margin with two setae near base. Maxilla and labium with shape and setae as figured (fig. 2). *Pronotum* (fig. 8) with a transverse row of six long, erect setae on anterior fifth, with a single sublateral similar seta near caudal fifth, and with a single long, lateral seta near caudal fourth or third; anterior and posterior fifth with cuticle paler in colour and with a semi-granulate microsculpture arranged in close and distinct longitudinal bands. Mesonotum similar to pronotum but with lateral caudal seta placed farther back so that it appears to form part of a row including caudal sublateral seta. Metanotum similar to mesonotum. Abdominal tergites two to eight similar to first (fig. 8); each with a posterior transverse row of four setae, this row being on posterior half or third on first tergite but nearer caudal margin on following tergites so that on
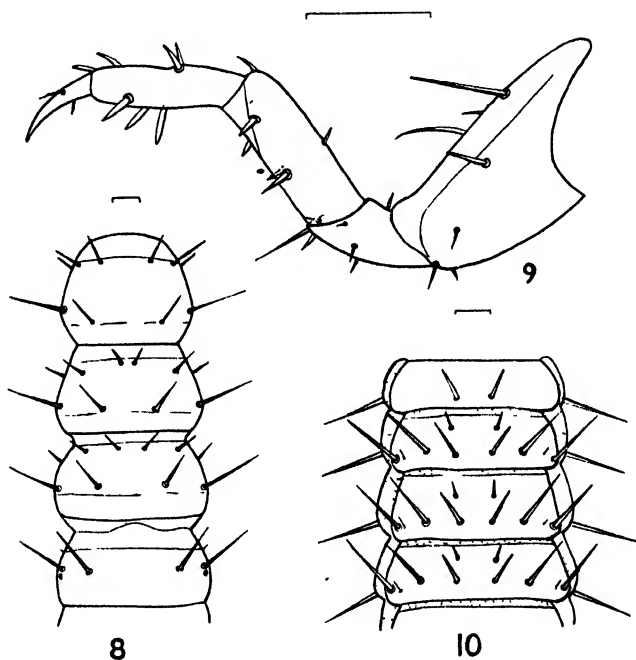
FIGS. 8–10.—Larva of *T. subterraneus* (L.). (8) Dorsal view of thorax and first abdominal segment. (9) Posterior view of left front leg. (10) Ventral view of first four abdominal sternites.

eighth it is on posterior fifth or sixth; sides of tergites with two to three very fine setae; ninth tergite with a single long seta on each side at postero-lateral angle and cuticle without a pale posterior belt. Urogomphi (fig. 6) as figured. Sclerotised part of tenth segment perfectly cylindrical, without pleural and sternal sutures, about as long as ninth tergite, and surface of cuticle with a number of fine, short, erect setae. Pleurites entirely membranous and without setae except for one moderately long, erect seta on anterior middle of mesopleurite anterior to spiracle. Sternite of first abdominal segment with a single caudal seta on each side of middle (fig. 10); sternites two to eight with a single, moderately short, anterior seta on each side of middle and a transverse row of six long setae on posterior fourth or fifth (fig. 11); ninth sternite without extreme lateral seta of posterior row and without the two moderately short anterior setae; on sternites two to eight there is fre-

quently a very fine, short, erect seta near inner base of extreme lateral seta of posterior row. *Legs* all similar in shape and chaetotaxy to front pair (fig. 9) but with hind pair distinctly longer.

Description of pupa of *T. subterraneus* (L.).

Male : Length, 4·5–5·0 mm.; breadth (which is greatest across first abdominal segment when wings are included), 1·7 mm. Body moderately strongly convex; abdomen sub-cylindrical in cross section. Cuticle white and densely, microscopically punctate; without fine hairs but with numerous long, moderately stout, finely spinulose, brownish seta
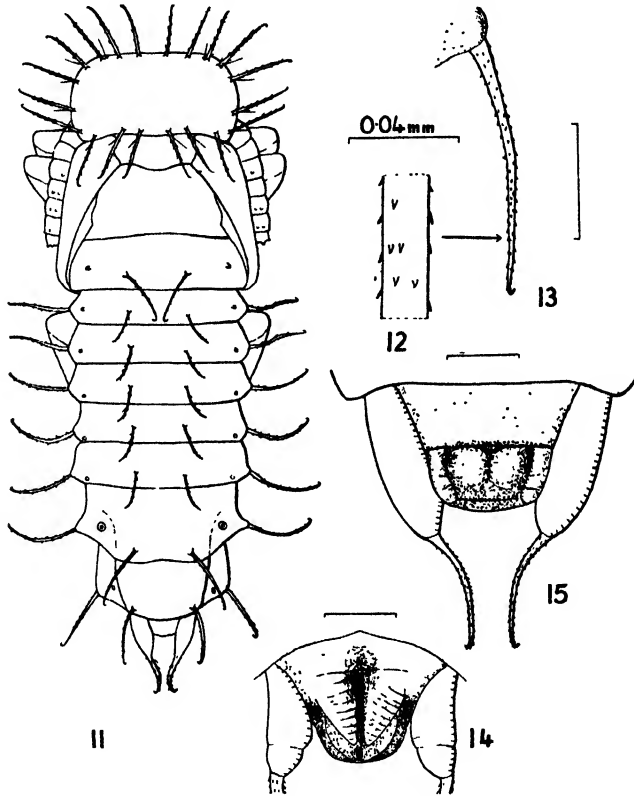
FIGS. 11–15.—Pupa of *T. subterraneus* (L.). (11) Dorsal view of male. (12) Enlarged portion of a spinulose seta. (13) A typical spinulose seta. (14) Ventral view of apex of female abdomen. (15) Same of male.

(figs. 12 and 13). *Head* completely concealed from above by pronotum. Surface without distinct impressions; on each side near mesal margin of eye with a longitudinal row consisting of three moderately long, erect, spinulose setae and posterior and slightly mesal to eye on each side of vertex with a single similar seta. Antenna extending posteriorly under lateral margin of pronotum and beyond to a point opposite posterior margin of meta-sternum; apical half of segments with a few low tubercles which become more prominent on five apical segments. *Pronotum* evenly convex and with shape and 20 setae as shown in fig. 11. Mesonotum very short and without setae; elytra extending caudally and slightly ventrally to a point opposite posterior margin of first abdominal segment. Metanotum

long, without impressions and without setae; wings extending caudally and ventrally to a point opposite posterior margin of fourth abdominal sternite. Abdominal tergites with shape and setae as figured (fig. 11); median setae of tergites two to six shorter than others of dorsal surface and with apices not curled over. *Metasternum* with a long, erect, stout, acute tubercle on each side of middle on posterior third of disk. Abdomen without setae on the sternites or at any rate without setae that have not been shown from a dorsal view (fig. 11); apical sternites as shown in fig. 15. *Legs* with all of tibiae and tarsi with numerous low tubercles; front pair with tarsi extending slightly beyond metasternal tubercles and at apex separated by a distance equal nearly to their length; middle legs with tarsi extending to a point opposite posterior margin of first abdominal sternite and separated by a distance equal to their length; hind legs extending slightly beyond posterior margin of fourth abdominal sternite and tarsi nearly contiguous at apex. *Spiracles* of abdomen on dorso-lateral sides of first seven tergites, those of first three opening on short, stout, feebly sclerotised tubercles; eighth segment with spiracles set in a slight depression and opening on middle of pleural membrane.

Female : Externally similar to male but with apical ventral part of abdomen differently formed (*cf.* figs. 14 and 15) and with two metasternal tubercles only about two-thirds as long.

The single female before me has a short, fine seta on each side of eighth tergite near long submedian seta, but this may be only an individual variation. The fine, moderately long, smooth setae that arise near bases of spinulose setae of the pronotum are often absent on one or more of the spinulose setae in both male and female.

I would here like to express my deep indebtedness to Drs. K. G. Blair and F. van Emden for the encouragement and help that they are always so ready to render in my work on the life-histories of beetles.

BOOK NOTICE.

Entomophagous Insects. By C. P. CLAUSEN. pp. x + 688, 257 figs. 8vo. London (McGraw-Hill), 1940. Price 49s.

This volume is one of the McGraw-Hill Publications in the Zoological Sciences and is uniformly bound with that series.

The book deals with all orders of insects which are known to contain representatives that feed upon other insects and, as is to be expected, the Hymenoptera occupy the greatest place—in fact the first 342 pages are devoted to that Order. After an introductory section the author deals with each Order family by family, describing host preferences; biology and habits; effect of parasitism upon the host; and immature stages.

A long list of references extending to some 50 pages is given and a very extensive index.

" The present volume represents, as nearly as possible, what the author himself would have liked to have had available while engaged in field work upon insect parasitology and the biological control of insect pests."

Particular attention is given in the volume to those insects with a high degree of specialisation in their host relationship, and the generalised predators are dealt with more briefly and only sufficiently to illustrate the host preferences and habits of each group.

BOOK NOTICE.

The Biology and Control of Wireworms. Review of Literature. By C. A. THOMAS. (*Bull. Pennsylvania State College School Agric. Exper. Stat.* **392** : 1–90.) 8vo. 1940.

This Bulletin comprises the following chapters : Biology, Life history, and Ecology; Environment; Biological Control of Wireworms; Insecticides used against Elaterid Larvae; Attrahents and Repellents; Planting Practices; Cultivation Practices; Crop Rotation; Miscellaneous Control Methods; Reviews of Literature on Wireworms; List of North American Investigators; Bibliography.

The work is intended for use in Pennsylvania in particular, but deals also with the problem of damage caused by the larvae of ELATERIDAE in the Temperate and Sub-tropical zones.

The work is, in a sense, a continuation of an earlier work by the same author published in 1930, and the literature reviewed is that published between 1930 and 1940.

" No attempt has been made to draw conclusions from this mass of information and the papers are summarised as nearly as possible in the form in which they were published."

Book Notice.

The Parasites of man in temperate climates. By T. W. M. Cameron. 8vo. Toronto (University of Toronto Press), 1940. Price $3. pp. xi + 182, front., 60 figs.

This work is intended for the medical man practising in the temperate and sub-tropical zones of the earth. Only parasites which occur in North America or Great Britain are discussed in detail but such as may be introduced in patients returned from the tropics are discussed briefly.

The book is divided in sections as follows : Protozoa; Helminths; Leeches; Arthropods; Technique and a Bibliography and Index.

Each parasite is described and often the life-history is given. The effect of the parasite on man is described and the medical treatment for the destruction of the parasites and the restoration of health is given fully.

There is a short statement covering the medical aspects of Myiasis.

THE DISTRIBUTION OF BUTTERFLIES IN THE MALAY PENINSULA (LEPID.)

By A. Steven CORBET, D.Sc., Ph.D., F.I.C., F.R.E.S.

(*British Museum, Natural History.*)

CONTENTS.

Apart from two specialised areas (one in the north-western state of Kedah and the other comprising the east coast islands of the Tioman group), British Malaya constitutes a homogeneous faunistic unit throughout which, subject to the restrictions of altitude and plant association stated below, the Rhopalocerous species are more or less uniformly distributed. Certain species are found only in the mountains, others are confined to the plains and a number occur at all elevations. A few species which appear to be strictly montane in Malaya proper [1] inhabit the plains in north Kedah. Most of the species are restricted to one or two of the three principal plant associations. These comprise primary forest, secondary growth in various stages of reversion to forest, which, in Malaya, is practically confined to the plains, and the coastal mangrove swamps, which often extend inland to a depth of several miles and occur more frequently on the west coast than on the east.

The equatorial belt is characterised by high temperature and humidity and heavy rainfall and these conditions favour a rich flora and fauna. With the butterflies, one brood succeeds another throughout the year, and the species are in flight continuously although, in the Malay Peninsula, some species are more abundant between December and May than during the remaining months of the year. There is no seasonal differentiation in Malaya proper such as occurs in monsoon areas but, with a few species, the "dry-season form" occurs as a rare aberration.

The species are not equally abundant. In the primeval forest, to which the majority are confined, they are represented by comparatively few individuals; the secondary plant associations are characterised by relatively few species which are present in large numbers, whereas butterflies are comparatively rare in the mangrove forests.

A substantial majority of the Malayan Rhopalocerous species are found also in the neighbouring islands of Sumatra and Borneo, while a minority appear to have reached Malaya from the north and do not extend south of Singapore. Many Malayan species range from north India through Sumatra and Borneo to Java and some of these occur also in Ceylon.

[1] Malaya proper is the term employed here to connote that part of British Malaya exclusive of the specialised areas of Kedah and Tioman mentioned above.

Geographical differentiation of species and subspecies in Kedah and the Tioman Islands.

It is well established that, as late as the Pleistocene Age, the present Malay Peninsula, the Large Sunda Islands (Sumatra, Borneo and Java) and their satellite islands, and almost certainly Palawan and Balabac also, were united to form a large continent which has been termed Sundaland (Molengraaf, 1921, *Geog. J.* **57** : 101). Most of this ancient land now lies beneath the sea and constitutes the Sunda Shelf, the depth of which nowhere exceeds 100 fathoms and is usually much less. It seems clear that Java was the first major island to be isolated, while the final separation of the Malay Peninsula from Sumatra is much more recent. What now remains of Sundaland is known as Malaysia

and comprises the three fairly clearly defined zoo-geographical sub-regions of Java, Neomalaya (consisting of the Malay Peninsula, Sumatra and Borneo), and Paramalaya, the last-named constituting the islands off the west coast of Sumatra.

The position regarding the land connection between Sundaland and the asiatic mainland is more obscure, but further light has been thrown on the subject by a study of the distribution of the Malayan Rhopalocera.

Of the 924 species of butterflies recorded from the Malay Peninsula, 35 are known only from a small area in the north-west corner of British Malaya which comprises the small northern state of Perlis, that part of Kedah north of the Kedah River, and the Langkawi Islands, which are situated 14 miles from the Kedah coast (fig. 1). In order to avoid constant repetition I propose in this paper to refer to this specialised area as " Kedawi." Of these 35 " endemic " " Kedawi " species,[2] of which three-quarters do not otherwise extend into Malaysia, 28 have been recorded from the Langkawi Islands and 20 from the north Kedah mainland and Perlis. The majority of these species are not rare stragglers in " Kedawi " but are well-established insects which, in many instances, are not uncommon. The subjoined Table I gives the extra-Malayan

TABLE I.

Distribution of the Malayan species of Rhopalocera outside the Malay Peninsula.

Family	Total in family	Species found also in				Endemic (not north of Mergui or south of Singapore)
		Ceylon	Burma, north of Mergui [3]	Sumatra and/or Borneo [4]	Java	
PAPILIONIDAE .	45	11 (24·4)	34 (75·6)	40 (88·9)	29 (64·4)	—
PIERIDAE . .	48	15 (31·3)	38 (79·2)	39 (81·2)	27 (56·6)	—
DANAIDAE .	39	9 (22·5)	25 (62·5)	31 (79·4)	26 (65·0)	1 (2·5)
SATYRIDAE .	53	4 (7·6)	35 (66·0)	41 (77·3)	25 (47·2)	—
AMATHUSIIDAE .	26	— (—)	12 (46·2)	21 (80·8)	8 (30·8)	2 (7·7)
NYMPHALIDAE .	144	27 (18·6)	99 (68·9)	124 (85·4)	92 (63·4)	—
LIBYTHEIDAE .	2	1 (50·0)	2 (100·0)	2 (100·0)	2 (100·0)	—
RIODINIDAE .	15	— (—)	10 (33·3)	12 (80·0)	7 (46·7)	—
LYCAENIDAE .	337	47 (13·9)	215 (63·6)	286 (84·8)	167 (49·4)	16 (4·7)
HESPERIIDAE .	215	34 (15·8)	166 (77·2)	175 (81·4)	105 (48·8)	1 (0·5)
Total .	924	148 (16·0)	636 (68·8)	771 (83·4)	488 (52·8)	20 (2·2)

The figures calculated on a percentage basis are shown in brackets.

distribution of the total Malayan species as far as Ceylon, Burma, Sumatra, Borneo and Java are concerned; Table II shows the same extra-Malayan

[2] The species here considered as " endemic " are, of course, only endemic in " Kedawi " with respect to British Malaya as a whole.

[3] For the purpose of this paper, species are regarded as Burmese in habitat only if found north of Mergui. Such a boundary precludes a few Malaysian species which have reached Victoria Point in southern Burma from being considered as Burmese.

[4] The Rhopalocerous fauna of Sumatra and Borneo is so much less well known than those of Burma, Malaya and Java that it appears preferable to consider them together, for it is highly probable that almost all the species found in two of the large components of Neomalaya will be discovered eventually in the third.

TABLE II.

Distribution of " Kedawi " " endemic " species outside the Malay Peninsula.

Total species	Species found also in			
	Ceylon	Burma, north of Mergui	Sumatra and/or Borneo	Java
35	8 (22·9)	33 [5] (94·3)	13 (37·1)	5 (14·3)

The figures calculated on a percentage basis are shown in brackets.

distribution for the " endemic " " Kedawi " species, and it is clear that these latter forms are distributed in a different proportion outside of Malaya.

From the above tables it is seen that, whereas over 80 per cent. of the total Malayan species are found also in Sumatra and/or Borneo and a little over two-thirds in Burma, in the case of the " endemic " " Kedawi " species, 95 per cent. occur also in Burma, while little more than one-third are known from Sumatra and/or Borneo.

It is a curious fact that several species which are more or less restricted to " Kedawi " as far as British Malaya is concerned, occur also in Sumatra and/or Borneo : such species are *Papilio aristeus* Stoll, *P. megarus* Westw., *Cepora nerissa* (F.), *Danaus similis* (L.), *Amblypodia anita* Hew., *Ticherra acte* (Mre.), *Marmessus scudderii* (Doh.), *Plastingia fuscicornis* (El. & Edw.), *P. noemi* Nic. and *Baoris unicolor* Mre.; one Kedah species, *Yoma sabina* (Cr.), is unknown from Sumatra and Borneo but occurs in Java.

A number of species common to both Malaya proper and " Kedawi " occur in the latter area as distinct geographical races. Leaving aside the " endemic " " Kedawi " species dealt with in Table II, of the 200 species examined by me from the Langkawi Islands, 36 are there represented by distinct subspecies : of the 117 species from the north Kedah mainland known to me, 9 occur as races distinct from the form from Malaya proper; one butterfly, *Lebadea martha* (F.), has well-differentiated races on the Langkawi Islands, on the mainland of north Kedah and in Malaya proper.

The present position regarding the " Kedawi " species and subspecies is summarised in the following table, in which the figures in brackets represent percentages.

	Total species known to me	Species confined to " Kedawi "	Subspecies distinct from those from Malaya proper	Subspecies identical with those from Malaya proper
Langkawi Islands . .	228 (100·0)	28 (12·3)	36 (15·8)	164 (71·9)
North Kedah mainland .	137 (100·0)	20 (14·6)	9 (7·3)	108 (78·1)
Whole of " Kedawi " .	276 (100·0)	35 (12·7)	41 (14·8)	200 (72·5)

The only other part of British Malaya inhabited by species which are not found throughout the Peninsula and by species present as well-differentiated

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[5] Including *Ariadne specularia* (Fruh.) and *Miletus archilochus* (Fruh.), which extend into Indo-China, but are not known from Burma.

races is the east coast islands of the Tioman group. These islands lie off the coast of the states of Pahang and Johore and are distant some 27 miles from the nearest point on the mainland. Of the 52 Tioman species examined by me,[6] 5 are not otherwise known from Malaya and 17 are represented in Tioman Island by distinct subspecies. In percentages :—

	Species confined to Tioman Is.	Subspecies distinct from those from Malaya proper	Subspecies identical with those from Malaya proper
Tioman Islands . . .	9·6	32·7	57·7

Thus, it will be seen that the Rhopalocerous fauna of the Tioman Islands is even more highly differentiated than that of " Kedawi," the differences between the two being statistically significant as shown by the χ^2 test.[7]

	Percentage species and subspecies confined to the area	Percentage subspecies identical with those from Malaya proper	Total
Whole of " Kedawi " . .	27·5	72·5	100·0
Tioman Islands . . .	42·3	57·7	100·0
χ^2	7·97	3·02	10·99
$n = 1$ $P < 0·01$	Difference highly significant		

There are no other areas in British Malaya showing a specialised fauna in any way comparable with those of " Kedawi " and the Tioman Islands. Singapore Island has a single resident species, *Pieris canidia* (L.), not found elsewhere in Malaya, *Tenaris horsfieldii* (Swains.) appears not to extend farther north than Johore, and the Singapore race of *Polyura hebe* (Btlr.) is distinct from that of the mainland. These differences, however, are slight, although Singapore Island shares a few species with Tioman Island and it is probable that a number of rather weak races of LYCAENIDAE could be discovered in Singapore were sufficient material available for study.

[6] Leaving aside *Euploea brookei* (Mre.) and *E. ochsenheimeri* Luc., which probably represent well-differentiated subspecies of *E. modesta* Bltr. and *E. midamus* (L.) respectively, but regarding which no definite statement· can be made pending a revision of the genus *Euploea* F.

[7] In this test of significance, χ^2 is calculated from the relation $\chi^2 = S\left(\dfrac{x^2}{m}\right)$, where m and $(m + x)$ are the expected and observed values respectively. The probability P of the difference between the observed and expected values occurring by chance is found by entering a table for χ^2 at the appropriate value for n, n being the number of degrees of freedom which, in the present examples, corresponds to the number of independent variables. On the usual $P = 0·05$ level of significance, differences are regarded as statistically significant when they can occur by chance not more frequently than once in twenty times. In all the examples in the present paper in which significant differences between observed and expected values are shown by the χ^2 test, P is less than 0·01, indicating that these differences could occur by chance less than once in 100 times (*vide* Fisher, 1934, *Statistical Methods for Research Workers* : 80).

From the above figures, it may be fairly concluded that the past history of the land area in the north-west of British Malaya which has here been termed " Kedawi " has not been identical with that of Malaya proper. The abrupt change witnessed in the Rhopalocerous fauna on proceeding north through Kedah suggests that, in comparatively recent times, there existed (and may still exist) somewhere in the neighbourhood of the Kedah River a natural barrier obstructing the passage of butterflies between south Burma and Malaya proper.

This discontinuity in distribution is not confined to the Rhopalocera. Ridley (1911, *J. Straits Br. R. asiat. Soc.* **59** : 15, 27) found the flora of the Siamese Malay States to be quite distinct from that of Malaya proper, many characteristic Malayan genera being absent, and he placed the boundary line near Alor Star on the Kedah River. The flora of the granite massif known as Kedah Peak (Gunong Jerei), in south Kedah, was found to pertain to Malaya proper and the same case obtains with regard to the butterfly fauna.[8] Ridley concluded that, in the not very remote past, the Malay Peninsula was separated from the mainland of Asia where Kedah now stands by an arm of the sea. Moreover, Gerini (1909, *Researches on Ptolemy's Geography of Eastern Asia* : 78–80) claims there is geological evidence to show that the land between Kedah and Singora (latitude 6°–7° N.) is an old sea bed.

Attractive as is the hypothesis of a former sea channel between Alor Star and the Gulf of Siam, there are difficulties in the way of accepting it as a complete explanation of the specialised flora and fauna of " Kedawi." In the first place, the topography of this region suggests that any such sea channel must have been situated farther north than Alor Star. Further, the geological formation of " Kedawi " is remarkable for a high proportion of limestone, although isolated limestone outcrops extend along the western side of the Peninsula as far south as the Batu Caves in Selangor [9]; in " Kedawi," the climate also is somewhat differentiated from that of Malaya proper and these factors must all be taken into account.

From the paper by Dr. Zeuner which follows, it will be seen that the probable explanation of the differentiated flora and fauna of " Kedawi " is that, while Malaya proper has undoubtedly been separated from the asiatic mainlain since the present species of butterflies came into being, it appears that this separation occurred north of Kedah, but the southward spread of certain immigrant species and subspecies from the present Siamese Malay States has been prevented by a barrier which is largely climatic. Although the total rainfall in " Kedawi " is not significantly less than in Malaya proper, the rainfall during the driest month is considerably less than that during the wettest month of the year, and in this important respect the climate of " Kedawi " approaches that of Burma. This effect of a dry season, which is accentuated on a limestone formation, appears to be an important factor in maintaining

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[8] For information regarding the butterflies of Kedah Peak (altitude 3978 feet), I am indebted to Mr. H. M. Pendlebury, Director F.M.S. Museums, who visited the mountain in 1928.

[9] Quite recently, Henderson (1939, *J. Malay. Br. R. asiat. Soc.* **17** : 24) has found that of 64 or 65 plant species recorded as confined to the limestone outcrops in the Malay Peninsula but with a distribution outside it, 50 are known only from localities north of Malaya on the asiatic mainland. The bulk of these northern plants, moreover, do not extend far into the Peninsula, most of them being confined to the Langkawi Islands, Kedah and Perlis. Mr. H. M. Pendlebury has reported (*in litt.* 26.ii.1941) that two " Kedawi " species of butterflies, *Papilio megarus* Godt. and *Everes potanini* (Alph.), have recently been taken by Mr. G. C. Stubbs round the limestone cliffs near Ipoh in Perak.

the distinctness of the " Kedawi " flora and fauna. To a lesser extent, the east coast of Malaya exhibits the same phenomenon of a dry seasonal effect (*vide* fig. 3 in the following paper), and it would be interesting to ascertain whether there is any tendency towards the formation of local races among the butterfly species which are most susceptible to such influences.

Relation between abundance of Malayan species and their extra-Malayan distribution.

The view that the most widely distributed species of plants and animals are the most abundant has been advanced a number of times (although I do not recollect having seen any quantitative evidence to this effect), and it is instructive to test this hypothesis with regard to the Malayan species of butterflies.

Table I gives the number of Malayan species found also in Ceylon, Burma north of Mergui, Sumatra and/or Borneo, and Java and, from the data which served for the compilation of this table, it is possible to separate the species into the following four distribution groups :—

(*a*) those species found north of Mergui but not south of Singapore (termed " northern " species);

(*b*) those found in Sumatra and Borneo, and with some species in Java also, but not north of Mergui (termed " southern " species);

(*c*) those ranging from Burma north of Mergui to Sumatra, Borneo and Java;

(*d*) as in (*c*) but found in Ceylon also.

In Table III the species found in these distribution groups are classified according to relative abundance. The figures for the abundance groups are based on the results of my own collecting during 5 years residence in British Malaya, such collecting being carried out as often as possible at all elevations and in all three plant associations.

Although it might be suggested that the ratio (specimens collected)/(number of species) should be taken as a measure of relative abundance, it appeared preferable to divide the species into groups according to abundance rather than to use the actual numbers collected. In this way, some allowance is made for species which occur in small colonies, but a further and more cogent reason for grouping is that, as little useful purpose was served by continued collecting of very common species in Malaya, such collecting was discontinued in each locality once a representative series had been obtained. Thus, with species in which more than 24 specimens were collected, in most cases larger numbers could have been obtained had attempts been made to catch all the butterflies seen. Nevertheless, even with the very common species, the numbers collected are still roughly proportional to the numbers seen.

In Table III the species are divided into five groups according to abundance : (*a*) very common species in which more than 24 specimens were obtained; (*b*) common species with 10 to 24 specimens, (*c*) less common species with 5 to 9 specimens, (*d*) rare species with 1 to 4 specimens, (*e*) very rare species of which no examples were caught. The *coefficient of abundance* in the last column in each row is calculated from the formula :

$$\frac{5\,(a) + 4\,(b) + 3\,(c) + 2\,(d) + (e)}{n},$$

n being the total number of species pertaining to the distribution group.

TABLE III.

Relative abundance of species according to distribution groups.

Distribution group	Total number of species (*n*)	Number of species in each frequency group					Coefficient of abundance
		(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	
PAPILIONIDAE and PIERIDAE.							
Northern . .	11	—	2	1	4	4	2·09
Southern . .	21	5	4	3	7	2	3·14
Burma to Java .	24	9	7	2	3	3	3·67
Ceylon to Java .	21	15	3	1	1	1	4·43
NYMPHALIDAE group (DANAIDAE to RIODINIDAE).							
Northern . .	35	4	4	4	11	12	2·34
Southern . .	86	14	13	14	18	27	2·64
Burma to Java .	76	22	17	4	28	5	3·30
Ceylon to Burma	34	14	10	2	5	3	3·79
LYCAENIDAE.							
Northern . .	20	—	1	2	8	9	1·75
Southern . .	92	3	11	9	29	40	2·00
Burma to Java .	93	11	13	15	24	30	2·47
Ceylon to Java .	42	10	11	12	6	3	3·45
HESPERIIDAE.							
Northern . .	33	—	1	4	10	18	1·64
Southern . .	44	—	3	4	15	22	1·73
Burma to Java .	67	7	7	7	21	25	2·25
Ceylon to Java .	23	1	4	9	6	3	2·74
Whole of Rhopalocera.							
Northern . .	99	4	8	11	33	43	1·96
Southern . .	243	22	31	30	69	91	2·28
Burma to Java .	260	49	44	28	76	63	2·77
Ceylon to Java .	120	40	28	24	18	10	3·58

It will be seen that, with all the four groups of families and with the total species, the " northern " species are the rarest, next in order come the " southern " species, then those distributed from Burma to Java, while the most widely ranging species (Ceylon to Java) are the most abundant. The " northern " species comprise the smallest group numerically, a not unexpected result which emphasises Malaya's much closer relationship with Sumatra and Borneo than with Burma.

Distribution of Malayan species according to altitude.

A range of mountains, which in general attains a height of about 4000 feet, runs from Kedah to north Johore, and there are many peaks, mostly on the main range, which reach altitudes up to 7000 feet. There are a few smaller parallel chains in Perak and Pahang.

Rather more than half the Malayan species of butterflies are confined to the plains, about a third of this number are found only on the hills and between a quarter and one-fifth of the total occur on both sides of the 2500-feet line which, for the purpose of this paper, is taken as the upper and lower limit

respectively for the plains and montane species. At this altitude the mean temperature is just over 70° F., as against 80° on the plains, and the annual rainfall exceeds the 90–100 inches of the plains. Here, also, differences in plant-life are apparent to the casual observer, and this division has the further advantage of practically restricting all the *Delias* species (PIERIDAE), other than *D. hyparete* (L.), to the montane group.

TABLE IV.

Distribution of Malayan Rhopalocera according to altitude.

	M Montane	P Plains	U All elevations	Total
PAPILIONIDAE and PIERIDAE . .	17	35	34	86
NYMPHALIDAE group . . .	34	130	89	253
LYCAENIDAE	59	197	68	324
HESPERIIDAE	25	137	30	192
Total	135	499	221	855

The totals are given in Table IV : species confined to " Kedawi " and to the Tioman Islands are excluded as they are not strictly comparable with the truly Malayan species from Malaya proper, and a few anomalous species (e.g. *Pieris canidia* (L.), which is confined to Singapore and is probably a comparatively recent introduction from south-east China), and those known only from one or two examples without sufficiently detailed data are also omitted.[10]

Of the species found only above or below the 2500-feet line included in the above table, 21·3 per cent. are montane and 78·7 per cent. pertain to the plains.

Although detailed information is now available regarding the distribution of most of the Malayan Rhopalocera, in two groups, the extensive genus *Arhopala* Bsdv. (LYCAENIDAE) and the family HESPERIIDAE, many of the species are extremely rare and the Malayan records often rest on a single specimen. As much more collecting is carried out below 2500 feet than above this altitude, it is evident that records of very rare species must show a bias towards the plains and, for this reason, it appeared preferable to omit the *Arhopala* and HESPERIIDAE from the calculation of the montane/plains ratio. The data thus amended are given in Table V.

The montane and plains species included in Table V occur in the proportions 25·1 per cent. and 74·9 per cent. respectively and this estimate is unlikely to be modified much by further discoveries. The χ^2 test shows there is no significant difference between the montane/plains ratio for the LYCAENIDAE (excluding

[10] The species thus excluded are : *Pieris canidia* (L.), *P. napi* (L.), *Euploea core* (Cr.), *Ypthima philomela* (L.), *Charaxes marmax* Westw., *Libythea narina* Godt., *Mahathala ameria* (Hew.), *Arhopala johoreana* Cbt., *A. malayana* B. Bkr., *A. tropaea* Cbt., *A. kurzi* (Dist.), *A. agamemnon* Cbt., *A. corinda* (Hew.), *A. cardoni* Cbt., *A. epimete* (Stgr.), *A. ammon* (Hew.), *Catapaecilma elegans* (H. Drc.), *Ritra aurea* (H. Drc.), *Poritia hewitsoni* Mre., *Hasora borneensis* El. & Edw., *Bibasis jaina* (Mre.), *B. gomata* (Mre.), *Choaspes furcata* Evans, *Celaenorrhinus nigricans* (Nic.), *Coladenia agni* (Nic.), *Koruthaialos kerala* Nic., *Erionota sybirita* (Hew.), *Plastingia flavia* Stgr., *Zela zeus* Nic., *Halpe sikkima* Mre., *Iton watsonii* (Nic.).

TABLE V.

Distribution of Malayan Rhopalocera according to altitude (excluding *Arhopala* and HESPERIIDAE).

	M Montane	P Plains	U All elevations	Total
PAPILIONIDAE and PIERIDAE .	17	35	34	86
NYMPHALIDAE group . . .	34	130	89	253
LYCAENIDAE (excluding *Arhopala*) .	50	136	57	243
Total	101	301	180	582

Arhopala) and that for the combined PAPILIONIDAE, PIERIDAE and families of the NYMPHALIDAE group.

	Percentages		
	Montane	Plains	Total
(a) PAPILIONIDAE, PIERIDAE and NYMPHALIDAE group	23·6	76·4	100·0
(b) LYCAENIDAE (excluding *Arhopala*) . .	26·9	73·1	100·0
χ^2	0·461	0·142	0·603

$n = 1$
P between 0·50 and 0·30
Difference between (a) and (b) not significant

If the " northern " and " southern " species are arranged in groups according to their occurrence above or below or on both sides of the 2500-feet altitude line, it is found that the proportion of M (montane), P (plains) and U (all elevations) species among the southern species is not significantly different from that of the total Malayan species as given in Table V.   On the other hand, the northern species occur in quite a different proportion, the montane species comprising nearly two-thirds of the total (Table VI).   As before, the species confined to " Kedawi " or to the Tioman Islands, together with the few anomalies and rare species with insufficient data (*vide* page 109), are omitted from the table and the genus *Arhopala* and the family HESPERIIDAE are also left out of consideration.

Reduced to round numbers, it may be stated that, of the total Malayan Rhopalocerous species under consideration which are confined either to the hills or the plains, 25 per cent. are montane as against 75 per cent. on the plains and the same ratio obtains with the " southern " species.   In the case of the " northern " species, 72 per cent. are montane as against 28 per cent. on the plains.

It has been shown already that, in Malaya proper, the " northern " species are consistently rarer than the " southern " species and it is evident that these insects of northern origin are the more recent arrivals, for, unless one postulates the highly improbable hypothesis that these same species, or a proportion of them, have already been established and subsequently become

extinct in the Large Sunda Islands, one must assume that they reached Malaya after the final severance of the Peninsula from Sumatra.

It may be mentioned that only 12 of the 45 " northern " species in Table VI are listed in Distant, 1886, *Rhopalocera Malayana*, as against 81 of the 154 " southern " species, but this is hardly a legitimate comparison as the montane

TABLE VI.

Distribution of " northern " and " southern " species according to altitude.

	" Northern " species				" Southern " species			
	M Montane	P Plains	U All elevations	Total	M Montane	P Plains	U All elevations	Total
PAPILIONIDAE and PIERIDAE	6	1	1	8	7	9	5	21
NYMPHALIDAE group.	15	6	4	25	4	35	35	74
LYCAENIDAE (excluding *Arhopala*)	7	4	1	12	14	35	10	59
Total	28	11	6	45	25	79	50	154
(a) Above as percentages	62·2	24·5	13·3	100·0	16·2	51·3	32·5	100·0
(b) Table V totals as percentages	17·4	51·7	30·9	100·0	17·4	51·7	30·9	100·0
χ^2	115·3	143·1	246·5	504·9	0·083	0·003	0·082	0·168
n	2				2			
P	<0·01				Between 0·95 and 0·90			
Difference between (a) and (b)	Highly significant				Not significant			

TABLE VII.

Relative abundance of " northern " and " southern " species with respect to altitude (excluding *Arhopala* and HESPERIIDAE).

	Totals	Number of species in each frequency group					Coefficient of abundance
		(a)	(b)	(c)	(d)	(e)	
Northern species :							
Montane	28	—	4	3	4	17	1·78
Plains	11	2	1	—	4	4	2·36
Total	39	2	5	3	8	21	1·95
Southern species :							
Montane	25	2	3	4	12	4	2·48
Plains	79	9	6	11	24	29	2·26
Total	104	11	9	15	36	33	2·32

species predominate in the "northern" group and there was little collecting above 2500 feet in Distant's day. Nevertheless, a comparison of the total specimens collected by me for the "northern" and "southern" species found above the 2500-feet line shows the northern forms definitely to be the rarer (Table VII).

If the Malayan Rhopalocera (other than *Arhopala* and HESPERIIDAE) are grouped into "montane", "plains" and "all elevations" (using 2500 feet as the dividing line as before), it is found that while two-thirds of the species in each altitude group occur also in Burma north of Mergui, a smaller proportion of the montane forms and a much greater proportion of the "all elevation" species extend to Sumatra, Borneo and Java (*vide* Table VIII).

TABLE VIII.

Distribution of Malayan altitude groups outside of the Malay Peninsula (excluding *Arhopala* and HESPERIIDAE).

	Total	Species found also in			
		Ceylon	Burma, north of Mergui	Sumatra and/or Borneo	Java
Montane . . .	101	7 (6·9)	68 (67·3)	67 (66·3)	37 (36·6)
Plains . . .	301	61 (20·3)	205 (68·1)	262 (87·0)	180 (59·8)
All elevations . .	181	36 (19·9)	122 (67·4)	177 (97·8)	134 (74·0)

The figures calculated on a percentage basis are shown in brackets.

Among the few species which are more or less strictly montane in Malaya proper and yet found on the plains in "Kedawi" may be mentioned *Papilio mahadeva* Mre., *Euploea leucostictos* (Gmel.), *Neptis harita* Mre., *Euthalia julii* (Lesson), *Celastrina cyma* Tox., *Arhopala ijauensis* B.Bkr. and *A. bazalus* (Hew.). It is, perhaps, worthy of note, that one or two species show a difference in habit in "Kedawi" and in Malaya proper. *Arhopala ijauensis* is essentially a primary forest species in Malaya and yet occurs in open secondary growth in "Kedawi"; the same difference in habit is shown by *Papilio coon* F. and *Lebadea martha* (F.).

Distribution of Malayan species according to plant association.

The primary forest is inhabited by a large number of species with a relatively small number of individuals, while the secondary plant associations are characterised by a comparatively small number of species which are each represented by numerous individuals. So much is apparent to every serious collector of Rhopalocera in the Malay Peninsula, but an examination of the available data shows that the secondary growth species are differentiated in other ways.

According to a list prepared mainly on the basis of my own collecting, but supplemented by evidence from other collectors, and excluding the species restricted to the specialised areas of "Kedawi" and the Tioman Island group, 117 species of Malayan butterflies can be regarded as pertaining to secondary growth associations; a few of these occur also in primary forest and others may be found rarely on the forest edge. The extra-Malayan distribution of these

secondary growth species is given in Table IX, where the terms " northern " and " southern " are applied as previously. About one-half of the 10 species grouped under " other distributions " are found in Burma, Sumatra and Borneo, and most of the remainder occur from Java, Sumatra and Borneo to China although absent from Burma. The last two columns in Table IX give the extra-Malayan distribution for the whole of the Malayan Rhopalocera based on the data in Table III.

TABLE IX.

Extra-Malayan distribution of secondary growth species.

	Secondary growth species		Whole of Malayan Rhopalocera	
	Actual numbers.	Percentages	Actual numbers.	Percentages
Northern	7	6·0	99	10·7
Southern	6	5·1	243	26·3
Burma to Java . . .	35	29·9	260	28·1
Ceylon to Java . . .	59	50·4	120	13·0
Other distributions . .	10	8·6	202	21·9
Total . . .	117	100·0	924	100·0

It is apparent from Table IX that the secondary growth butterflies in Malaya are mostly widespread species, half of which are found from Ceylon to Burma, through Neomalaya, to Java; compare this with the 13 per cent. of the whole of the Malayan Rhopalocera with the same range.

It is interesting to note that, as far as the butterfly fauna is concerned, the Krakatau Islands in the Sunda Straits have been recolonised very largely by secondary growth species which are distributed from Ceylon to Burma, Neo-malaya and Java. These islands were the scene of a catastrophic volcanic eruption in 1883, when they were covered with hot ashes and pumice to a depth of over a hundred feet and the vegetation was entirely destroyed. By 1928, 30 species of butterflies were known from the islands but, of these, 6 Hesperiids must be left out of consideration as their identification is uncertain. The remaining 24 Krakatau species fall into distribution groups as under :—

Northern species	0
Southern species	4
Burma–Java species	5
Ceylon–Java species	15
Total	24

All of the Krakatau species occur in both the neighbouring islands of Sumatra and Java.

The reversion of cleared land to primary forest in the equatorial belt takes place in a series of stages in which one plant succession follows another. As the degree of shading increases, certain sun-loving plant species characteristic of the earlier stages disappear and are replaced by species preferring shade. It is evident that, before the present large-scale interference with nature by man in

Malaysia, areas of secondary growth at more or less the same stage of development, and so harbouring the same plant species, must have been few and far between. The continued existence of certain species of Lepidoptera whose larvae feed on plants confined to the secondary growth association during its early stages would only be assured if such insects were able to move on from one cleared area to others at the same or at a slightly earlier stage in the reversion process when the food-plants disappeared or when limited supplies were exhausted. It may well be that the phenomenon of migration in Lepidoptera owes its origin to this continual necessity on the part of secondary growth butterflies to discover and to colonise new areas of secondary plant associations at certain stages of development, for the majority of the Indo-Malayan species of butterflies listed as migratory by Williams (1930, *Migration of Butterflies*) are secondary growth species in Malaya having an extra-territorial distribution at least from Ceylon to Burma, through Neomalaya, to Java.

TABLE X.

Relative abundance of Malayan Rhopalocera according to families.

	(i) Total species	(ii) Total specimens collected	Ratio $\frac{(ii)}{(i)}$	Number of species in each frequency group					Coefficient of abundance.
				(a)	(b)	(c)	(d)	(e)	
PIERIDAE .	48	1326	27·6	19	13	2	6	8	3·60
DANAIDAE .	39	817	20·9	12	7	1	10	9	3·07
PAPILIONIDAE .	45	724	16·1	10	9	7	12	7	3·07
NYMPHALIDAE .	144	1956	13·6	34	25	21	38	26	3·03
SATYRIDAE .	53	677	12·7	8	13	7	15	10	2·88
LYCAENIDAE .	337	2274	6·8	25	38	42	94	138	2·16
RIODINIDAE .	15	87	5·8	—	3	3	7	2	2·47
AMATHUSIIDAE .	26	134	5·2	1	4	1	10	10	2·08
LIBYTHEIDAE .	2	10	5·0	—	1	—	—	1	2·50
HESPERIIDAE .	215	1026	4·8	10	18	26	68	93	2·00
LYCAENIDAE subfamilies arranged separately.									
LYCAENINAE .	91	1403	15·4	17	20	18	21	15	3·03
MILETINAE .	27	181	6·7	2	2	5	8	10	2·18
THECLINAE .	201	678	3·4	6	16	19	58	102	1·83
PORITIINAE .	17	11	0·6	—	—	—	6	11	1·35

Of certain families of Rhopalocera, notably PIERIDAE, DANAIDAE and the subfamily LYCAENINAE, a relatively large proportion of the species favour secondary plant associations rather than primary forest. On the other hand, in the AMATHUSIIDAE, HESPERIIDAE and the subfamily THECLINAE, most of the species are true denizens of the forest. An estimate of the relative abundance of the Malayan butterfly species by families based on the results of my collecting from 1927 to 1932 shows the PIERIDAE and DANAIDAE to be the most abundant, and the AMATHUSIIDAE, HESPERIIDAE and THECLINAE to be the rarest (Table X). It will be seen that, except for the very small families LIBYTHEIDAE and RIODINIDAE, the families follow the same order whether arranged according to the coefficient of abundance or the ratio (specimens captured)/(species in family).

It is hardly a matter for surprise that there is a paucity of data regarding the

distribution of butterflies in the crocodile-infested mangrove forests which fringe the more sheltered parts of the Malayan coast. Few butterflies were seen during my few visits. There are, however, a few species of Malayan butterflies which are entirely restricted to this plant association : these are *Danaus affinis* (F.), *Tenaris horsfieldii* (Swains.), *Rapala drasmos* H. H. Drc. and *Suastus gremius* (F.), all of which are very rare in collections and by no means common where they occur.

Distribution frequencies of Malayan species of butterflies.

From the figures for relative abundance given in the tables on previous pages, it is very evident that the Malayan species of butterflies are not equally common. In fact, the frequency distribution of the species collected by me under the conditions detailed on page 107 resembles the "hollow curve" of Willis (1922, *Age and Area*) (*vide* Table XI). The numerically largest group comprises

TABLE XI.

Distribution frequencies of species collected in Malaya from 1927 to 1932.

S	n	S	n	S	n	S	n
304	0	10	19	3	38	1	59
118	1	10	20	3	39	2	60
74	2	11	21	1	40	1	64
44	3	5	22	1	41	1	66
24	4	3	23	2	42	1	68
29	5	3	24	1	43	1	70
22	6	5	25	1	44	4	71
20	7	4	26	4	45	1	76
19	8	8	27	2	46	1	84
20	9	3	28	1	48	1	89
15	10	3	29	2	49	1	92
12	11	2	30	3	50	1	93
14	12	5	31	1	51	1	100
6	13	4	32	2	52	1	105
12	14	7	33	1	53	1	108
6	15	4	34	4	54	1	119
9	16	5	35	1	55	1	141
9	17	3	36	5	56	1	147
6	18	3	37	2	58	1	194

The figures in the columns headed S show the number of species of which n specimens were obtained.

Thus, 620 species were represented by the 9031 specimens collected. The species of which 194 specimens were obtained was *Eurema hecabe* (L.).

species of which no specimens were obtained; next follow species represented by single examples, then species with 2 specimens and so on. If the values given in Table XI are converted into their respective logarithms, it is found that, between $n = 1$ and $n = 24$, the plot closely approximates to a straight line, and the relation between S and n is expressed by the equation :—

$$S = C/n^m$$

where m and C are constants.

The results for each Rhopalocerous family taken separately show the same exponential distribution, but it is obvious that, had collecting been continued, with a consequent increase in the number of species represented, the frequency diagram would show a maximum which would gradually rise as more and more specimens were obtained.

As this mathematical aspect of the distribution of species has an important bearing on the matter of collecting biological material in equatorial countries, it is hoped that it may be possible to return to the subject on a future occasion.

SUMMARY.

It has been found that an area in the north-west corner of British Malaya (here termed " Kedawi " for convenience of reference), and the east coast islands of the Tioman group constitute two specialised faunistic areas characterised by the presence of species not otherwise found in Malaya and by geographical races which are distinct from the corresponding forms from Malaya proper. The boundary line separating " Kedawi " from Malaya proper is in the neighbourhood of the Kedah River, and Ridley found this same line constituted the northern limit of the flora of Malaya proper. Ridley postulated a former sea channel where Kedah now stands, but a more probable explanation is that, while the present Malay Peninsula has undoubtedly been separated from the asiatic mainland since the advent of the present species of butterflies, this separation occurred north of Kedah and the southward spread of insects and plants has been obstructed by a barrier which is largely climatic. Evidence put forward in the present paper shows that the union or reunion of Peninsular Malaya with the asiatic mainland was effected after the severance of Malaya from Sumatra and the other Large Sunda Islands.

The distribution of Malayan Rhopalocera has been studied quantitatively with respect to abundance, altitude, plant association and extra-Malayan distribution. The majority of the Rhopalocerous species in Malaya proper are of Malaysian origin, probably arising when Malaya, Sumatra, Borneo and Java were united to form the continent of Sundaland, but about one-tenth of the total have reached Malaya from the north after the separation of Malaya from Sumatra : these latter species are comparatively rare and largely confined to the mountains. On the other hand, the most abundant species in Malaya are those with the most extensive extra-Malayan distribution : a large proportion of these widespread insects are characteristic butterflies of secondary growth plant associations, and the recolonisation of the Krakatau Islands has been largely effected by butterflies thus characterised.

GEOLOGY, CLIMATE AND FAUNAL DISTRIBUTION IN THE MALAY ARCHIPELAGO

By F. E. ZEUNER, Ph.D., F.G.S., F.Z.S.

IN his most valuable paper on the distribution of the butterfly fauna of Malaya, Dr. Corbet states that the extreme north-west of British Malaya (North Kedah, Perlis and the Langkawi Islands) differs remarkably from the remainder of the Peninsula (called Malaya proper), the number of Burmese species being proportionately much larger and there being a number of species occurring in races distinct from the forms from Malaya proper. The fauna of the Langkawi Islands is even more highly differentiated than that of the adjacent mainland, but in view of the common features the entire area is considered as a unit, which is called Kedawi. It is evident that some factor, or factors, has set a limit to the further extension of the Kedawi fauna into Malaya proper, and such factors can either prevail at the present day, or have acted in the immediate past, *i.e.* the Pleistocene.

An even more marked differentiation has been observed on Tioman Island, off the east coast.

The taxonomic differences involved are without exception of less than generic value. It is unlikely, therefore, that the factors which might have influenced the evolution and geographical restriction of species and subspecies date further back than the late Tertiary, and the great majority of forms are most probably not older than the Pleistocene.

In connection with the differentiation of new varieties and their (apparent or real) consolidation as subspecies or species, the following main factors have to be considered.

(1) Geographical changes : connections and disconnections of parts of the Archipelago :

     (1a) due to tectonic movements,

     (1b) due to fluctuations of the sea-level.

(2) Geological strata and soils.

(3) Climatic conditions, past and present :

     (3a) Climatic fluctuations during the Pleistocene,

     (3b) Present-day climatic conditions.

(1a) The Malay Archipelago consists of a stable block, Sundaland, comprising the Peninsula, eastern Sumatra, part of the north coast of Java, Borneo and the sea basin between them and, on the other hand, the outer zone of the mountains of Sumatra, Java, the Lesser Sunda Islands, Celebes, etc. The outer zone, much of which is volcanic, is in a state of tectonic activity (Brouwer, 1925; Scrivenor, 1941), and considerable earth movements have taken place here during and after the Tertiary. There is plenty of evidence that they still continue. It is impossible, however, to account for these movements in the attempted reconstruction of the Pleistocene conditions which follows. They have to be borne in mind as a possible source of error but, fortunately, they hardly affect the comparatively stable block of Sundaland.

(1b) It is known that, since the beginning of the Pleistocene, the sea-level has undergone repeated fluctuations. These were chiefly due to the formation of large ice-caps in the higher latitudes, resulting in a drop in sea-level, and to

the more or less complete melting of the ice during the interglacials and after the Last Glaciation, resulting in high sea-levels. The high sea-levels of the earlier phases were higher than the present (as much as 100 m. in the Sicilian phase, earliest Pleistocene). The standard succession for the phases of high and low sea-levels has been worked out in the Mediterranean, but evidence shows that it applies also to other parts of the earth, including South Africa and Australia (for details, *see* Zeuner, *Geology Prehistory and Time*, in preparation). One is justified, therefore, in assuming that the same or very similar levels apply to the Malay Archipelago, though local evidence is still scanty.

1
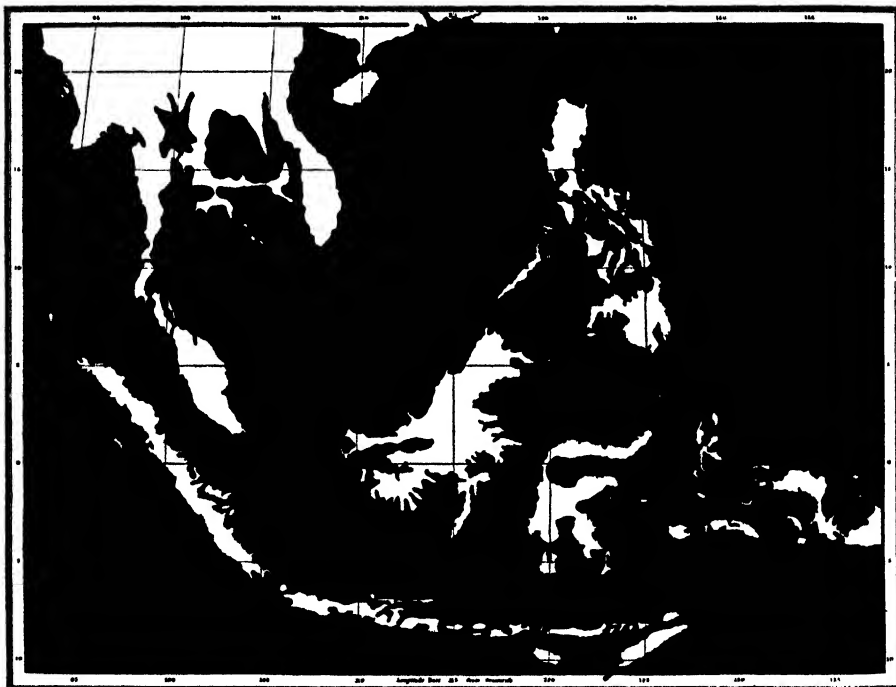
FIG. 1.—Submergence of the Malay Archipelago by 100 m. (330 ft.). Based on the 100-m. contour and various levels given in recently published maps, chiefly from the Atlas van Tropisch Nederland, 1938. A submergence of about 100 m. occurred in the earliest Pleistocene (Sicilian phase); the sea-levels of later phases were not so high (Milazzian 60 m., Tyrrhenian 32 m., Monastirian 19 and 7·5 m.). The chart represents the maximum of disconnection in the Archipelago and, therefore, the maximum of marine barriers to faunal and floral migration.

Evidence for former *high* sea-levels along the coast of Malaya proves that the sea once stood at least 50 ft. higher than at present, whilst certain observations suggest as much as 200 or 300 ft. (Scrivenor, 1931), figures which are in keeping with the Mediterranean evidence. A sea-level only 50 ft. higher than the present would submerge considerable portions of Sumatra and Borneo, and part of the coastal plain of the Peninsula. A submergence of about 300 ft. would produce much greater modifications (fig. 1). The Peninsula would be severed from the continent of Asia by a fairly broad sea-channel approximately

between Trang and Bandon in Siam (now used by a railway). In addition, at least two further, narrow, channels may have been formed, one across the Isthmus of Kra (76 m). and one in northern Perlis (92 m. at Padang Besar). It is of course not strictly permissible to transfer the present-day topography to earlier phases of the Pleistocene, since erosion and deposition cannot be taken into account. One cannot be certain therefore whether narrow gaps like those of Kra and Padang Besar were sea-channels or not, but there is a possibility of it having been so. Moreover, other such gaps are bound to be discovered as the work of the cartographers proceeds in these little-known regions. Thus, it is likely that, in the earliest Pleistocene and possibly later, during the phases of high sea-level, the Malay Peninsula formed a chain of islands, with Malaya proper as the largest member.

2

FIG. 2.—Maximum amount of land-exposure during the Pleistocene phases of low sea-level. 200-m. depth-line used, the 100-m. and 70-m. lines not being at present available for the entire area. The 200-m. and 100-m. lines are, however, close to one another almost everywhere, so that the difference is negligible in small-scale charts. Submarine river-channels based on Dutch maps and papers. Material: Atlas van Tropisch Nederland, 1938, and other charts and maps chiefly of Dutch origin.

Evidence for a considerable *drop* in sea-level at a certain stage (or stages) of the Pleistocene is abundant in the Archipelago (Molengraaff, 1921, 1930; Umbgrove, 1930) and points to a coastline of about −100 m. (Umbgrove) or possibly a little less (Daly, Molengraaff). The river-channels of Sumatra and Borneo, which have been traced beneath the present sea-level in connection with mining operations, form part of a large system that discharged into the

China Sea near the island of Great Natuna. Unfortunately, no charts are at present available for tracing the −100 m.-line for the whole archipelago and the −200 m.-line had to be used in fig. 2 instead. The two lines are close to one another wherever this can be ascertained, so that the general picture of distribution of land and sea at a sea-level of −100 m. is very nearly the same as at −200 m. A low level of −100 m. has been claimed for the Last Glaciation. Some workers, however, are inclined to assume a drop to −200 m. for the earlier glaciations. Fig. 2 clearly shows the compact mass of Sundaland. It also shows that the Wallace Line persisted through a phase of low sea-level, as did the Weber Line separating the Australian block from the Archipelago.

In interpreting faunal relations by means of the maps, figs. 1 and 2, it has to be remembered that conditions of this type alternated repeatedly during the Pleistocene.

(2) The rocks of any area influence, directly or indirectly, flora and fauna. In the case of butterflies, the soils developed on certain types of rock will determine the character of the flora on which, in turn, the caterpillars depend for food. From this point of view it is important that Langkawi, Perlis and north Kedah (and probably adjacent Siam also) contain considerable areas of limestone (Scrivenor, 1931). It will be necessary to return to this point when discussing the present climate.

(3a) Since the several glaciations which occurred during the Pleistocene in the temperate regions modified the climates of the non-glaciated regions, one would expect to find that the Malay Archipelago also was affected. Scrivenor (1941) holds that the climate was cooler during the Pleistocene (*i.e.* in certain phases) and relies on evidence of a former greater glaciation of New Guinea. However much or little there might have been of a cooling of the atmospheric climate, the lowering of the sea-level must have enlarged the areas of mountain climate. Conversely, a rise of sea-level might have favoured the formation of isolated mountain faunas. Repeated climatic fluctuations undoubtedly occurred in the Malay Peninsula during the Pleistocene and influenced fauna and flora, but our knowledge regarding this area is still entirely theoretical.

(3b) There remains the question of the extent to which the present-day climate might limit the distribution of species or subspecies and give the impression that there was, in the past, a geographical barrier of some sort. It is essential to examine this point because of the peculiar character of the Kedawi fauna as established by Dr. Corbet. In the tropical zone, slight differences in temperature are less likely to affect butterflies than is the occurrence of a dry season.

There are several types of climate in British Malaya (Stewart, 1930), some with one fairly distinct drier season, and some with two comparatively dry seasons. From the present point of view it does not matter when these occur so long as they are pronounced. For this reason, I have calculated a *seasonal index*, expressing the rainfall of the driest month in per cent of that of the wettest. The material was provided by Stewart's tables. The index proves to be lowest for climates with a pronounced dry season.

It is conceivable, however, that the *total annual rainfall* at any one place is so high that even the driest month is still damp enough to prevent an influence on the flora and fauna from becoming noticeable. In fig. 3, therefore, the index is plotted against the annual total of rainfall for each of the 55 stations given by Stewart.

The result is most illuminating. Whilst " Malaya proper " constitutes a comparatively uniform region with the rainfall of the driest month being one-third to two-thirds of the wettest, two areas with pronounced dry seasons are
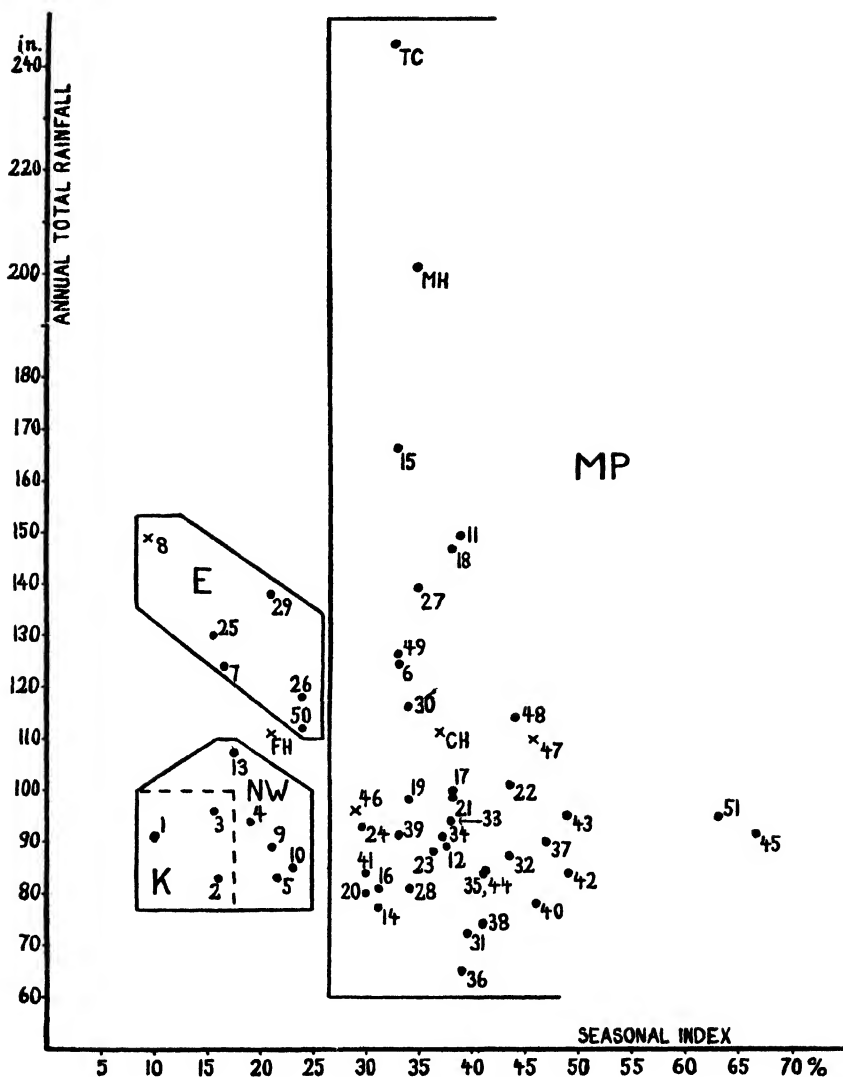
FIG. 3.—The seasonal variation of rainfall in British Malaya. Seasonal index (driest month : wettest month) plotted against annual total. Dot : Station with 10 or more years' record. Cross : Station with less than 10 years' record. Numbers of stations as in Stewart, 1930 : 1. Langkawi, 2. Perlis, 3. Alor Star, 51. Singapore.   MP : Malaya proper.   E : East coast.   NW : north-west of British Malaya.   K : Kedawi region of Dr. Corbet.   This has the greatest seasonal differences.   Based on tables in Stewart, 1930.

revealed. One is the east coast; it is not of interest in this context. The other is the north-west corner of British Malaya, including Dr. Corbet's Kedawi. This north-west area is not the driest part of British Malaya, since the annual total is, in the average, much the same as in Malaya proper, but it has the greatest seasonal extremes. The driest month receives from one-tenth to less than one-quarter of the rainfall of the wettest month. Within the north-west area, the three stations belonging to Kedawi (1. Langkawi, 2. Perlis, 3. Alor Star) are, in turn, the most extreme, and the absolute extreme is represented by Langkawi Island. These conditions indicate an approach to the climate of Tenasserim, Burma proper, continental Siam and Indo-China, where for instance at Tavoy, Rangoon, Bangkok and Saigon at least one month without any rainfall is encountered. If one now recalls that limestone covers considerable areas in Kedawi and that limestone everywhere accentuates dryness because of its permeability, it is easy to understand that many plants and insects of the Burmese sub-region were able to extend their area as far south as Kedawi but not farther into Malaya proper. It is highly probable, therefore, that the southern limit of the Kedawi fauna is, at present, climatic.

This result is of more than local significance, since it has been suggested more than once (most recently by Setchell, 1930) that the eastern boundary of the Malaysian sub-region (the Wallace Line) also is not merely geographical, but partly determined by the climate which, from Lombok eastwards, shows a very pronounced dry season (seasonal index for Kupang, Timor, 0). In Java, the transition from the typical Malaysian climate to the climate with a dry season may be observed. Buitenzorg is in total rainfall and seasonal index (51) similar to many stations of Malaya proper, but in Batavia, the seasonal index is only 9, and in Pasuruan, 2. This, in conjunction with its geographical position on the south-eastern edge of Sundaland, explains the comparatively great difference of the Javanese fauna from that of Sumatra, Borneo and the Peninsula.

Thus, it appears that the Malaysian sub-region with its rain-forest climate is at the present day bordered in the north and in the south-east by areas with a climate with pronounced dry seasons. The transition from one type of climate to the other coincides in both cases with geographical obstacles to migration : in the north, the bottleneck of the northern part of the Peninsula, in the south-east, the sea channel between Bali and Lombok. The present-day conditions thus explain very well why the uniform character of the Malaysian fauna is being maintained.

During the Pleistocene, conditions similar to those of the present day are likely to have prevailed during the interglacial phases of high sea-level. At certain phases, the Peninsula may even have been detached completely from the Asiatic continent (fig. 1). Conditions were even less favourable for faunal migration and intermingling than they are now. On the other hand, the isolation of Malaya proper, Sumatra, Borneo and Java from one another and from the continent must have favoured the evolution of geographical races.

During glacial phases, the sea-level was lower than at present, and the islands were connected by lowlands traversed by rivers. Each time this happened the faunas of Malaya, Sumatra, Borneo and (to a minor extent) Java met and mingled in these lowlands. This must have contributed greatly to maintaining the uniformity of the Sundaland fauna. The climatic character of these lowlands is not likely to have been very different from that of the tropical rain forest at any time during the Pleistocene. These lowlands are traversed by the equator and must always have been within the equatorial belt

of ascending air, even if the temperature was at times somewhat lower than now.

During the low sea-level phases, Sundaland was in broad connection with the Asiatic continent (fig. 2), and exchange of faunal elements was then easier than at other times. The mountainous nature of Burma, southern China and Indo-China, however, must have presented a barrier to many species of the rain-forest fauna, and in addition it is highly probable that the climate of Further India as a whole differed from that of Sundaland just as much as does now the climate of the Archipelago from that of Burma and Indo-China, so that the sub-regional character of the Malaysian fauna was largely maintained. The eastern limit to which the Sundaland fauna could expand without encountering a sea-channel, was Palawan, Borneo and Bali. In the south-west, the Mentawi Islands were separated from Sumatra by a wide sea-channel (except near Batu), but Nias only by a very narrow sea-passage. This explains why the fauna of Mentawi differs more from that of Sumatra than does the fauna of Nias. This is a typical case of geographical differentiation, in which the climate plays no recognisable part.

Another very striking case of geographical isolation without a recognisable influence of the climate is that of Tioman Island, studied by Dr. Corbet. It lies some distance off the east coast of Malaya in a shallow sea, and is topped by a mountain 3400 ft. high. While the sea-level was high (as at present), Tioman was completely severed from Malaya, and an island mountain fauna developed which now contains a surprisingly high number of species and sub-species confined to the island (42% among the butterflies, found by Dr. Corbet). When the sea-level was low, Tioman was linked with Malaya proper by lowlands which still presented a barrier to an exchange of mountain species and races between Tioman and Malaya, so that the peculiar character of the island fauna was largely preserved even during the phases of low sea-level.

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Book Notice.

Insect Pests of stored grain and grain products. Identification, habits, and methods of control. By R. T. Cotton. 8vo. Minneapolis, Minnesota (Burgess Publishing Co.), 1941. pp. 242, 93 figs. Price $3.

This book is printed by offset lithography in imitation typewriting, the figures, including photographs, being reproduced with the text. The volume is bound by a metal hoop threaded through a series of holes linking the single leaves on which the letterpress is printed.

The author is Senior Entomologist at the United States Bureau of Entomology and Plant Quarantine, and many of the figures are reproduced from publications of the Department. The eleven chapters are entitled: Insect pests of stored grain and milled cereals; Controlling stored grain insects on the farm; Control of insects in grain stored in elevators and warehouses; The insect problem in flour mills; Practical control methods in the mill; Protecting flour after manufacture; Fumigants and fumigation; The common fumigants; Flour mill and warehouse fumigation; Fumigation in atmospheric vaults and vacuum chambers; Heat sterilization in the flour mill.

The book is a handbook to the whole subject of controlling insect pests of stored grain and grain products. It is noteworthy that the most effective measures described are fumigation by one or other of the poison gases and some of the illustrations of men at work in their gas-masks are strangely familiar to the present-day reader in Europe.

Stress is laid on the desirability of preventing infestation so far as possible since, in the case of stored products, prevention is certainly better than cure.

The publishers ask that orders for the book from abroad should be accompanied by a remittance, when the book will be sent post free.

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HENRY SMEATHMAN [?-1786]

By Francis J. GRIFFIN.

HENRY SMEATHMAN, author of " Some account of the termites, which are found in hot Climates" published in 1781 (*Phil. Trans. Roy. Soc.* 71 : 139–192, 4 pls.), is one of the least known entomologists despite the fact that this work is probably one of the most widely quoted of any on Natural History.

Hagen 1863 (*Bibl. Ent.* 2 : 168) states that he was a teacher of languages, that he travelled in Africa and died in 1787. Smeathman certainly visited Africa, even though his travels were restricted, but he died in 1786 and not 1787 as is proved by his obituary notice published in 1786 (*Gentleman's Magazine* 56 (2) : 620) as follows : " At his apartments in Cannon-str. Henry Smeathman, esq.; of Clements-inn, author of the history of the Termites or Black [sic] Ants. See Phil. Trans. vol. LXXI. p. 139, and our vol. LI. p. 526. He was also author of the humane plan for the comfortable and free settlement of Black Poor on the Coast of Africa (see p. 504), and of many ingenious treatises not yet published. He was sometime secretary to the London Chamber of Commerce."

Apart from this obituary notice little published information is available concerning Smeathman, and that little is widely scattered in different publications of a non-entomological nature. For this reason I have gathered together the scraps and added such unpublished information as I can find. The result is a story not without interest despite the passing of over a century and a half since Smeathman's death.

In Smeathman's day Africa was still very much the " Dark Continent," slave trading was still an active pursuit, and America was still a British Colony. In all these Smeathman played a part, for he visited Africa for 4 years and left that continent to reside in the West Indies, he-propounded a plan, which was adopted after his death, for the settlement of liberated slaves in West Africa, and was in close contact with several of the leading actors in the events concerned with the loss of America as a British Colony. His visit to Africa was primarily to collect specimens, but he corresponded with Linnaeus and sent him undescribed plants from Africa. He was apparently connected with the law, for he is described as "-of Clements-inn ", and was for a time Secretary to the London Chamber of Commerce. He is known to have invented an aeroplane and to have experimented with balloons. In short, his life was full of activity and endeavour.

It is in connection with his visit to Africa that Smeathman is of most importance to Entomology. Much information on this episode in his life is to be found in an unpublished letter-book of Dru Drury covering the years 1761 to 1783, which covers the whole period of Smeathman's stay in Africa. This interesting volume, in Drury's handwriting, was presented to the British Museum (Natural History) in June 1937 by Mr. Charles Dru Drury of Sunderland, a descendant of its author, and I am indebted to Mr. Riley of the British

Museum, in whose charge the volume now is, for enabling me to consult it in London. The story of the volume has been told by Professor T. D. A. Cockerell in 1922, " Dru Drury, an eighteenth century Entomologist ", *Scientific Monthly* **17** : 67–82.

Dru Drury, who lived from 1725 to 1804, was a London Goldsmith who became Goldsmith to the Queen. He is best known today on account of his great work in 3 volumes entitled *Illustrations of Natural History* 4to. 1770–1782. According to the letters, Drury invited Smeathman to write the third volume of the work in 1773, but the offer was declined. He was a great collector of insects, and Leach in 1815 (*Edinburgh Encyclopedia* **9** : 66) says of his collection that it " was one of the most extensive ever made, and is said to have contained, in species and varieties, no less than 11,000 insects, (in his time the largest collection,) . . . he offered sixpence an insect for all insects, ' from the size of a honey-bee upwards '. His Museum of Entomology was disposed of, in London, by public auction, and produced about six hundred pounds. One insect, viz. *Scarabaeus Goliathus*, (*Goliathus magnus*,) was purchased by Mr Donovan, for twelve guineas and a half, who obtained also all the British insects, (which were very numerous,) collected by Mr Drury, and now enrich his splendid museum." I understand that a copy of the sale catalogue is in the Hope Department at the Oxford Museum. Late in his life Drury became bankrupt but, with the help of his friends, his fortune was to some extent re-established. He lies buried in the church of St. Martins in the Fields in London. Drury was the President of one of the first recorded entomological societies " The Society of Entomologists of London [1780–1782] " (see Griffin, 1940, *Proc. R. ent. Soc. Lond.* (A) **15** : 51). It is quite apparent from his letters that he was on the friendliest of terms with Smeathman and it is possible that the original suggestion that Smeathman should visit Africa was made by Drury. Seventeen letters from Drury to Smeathman are included in the collection covering the years 1768 to 1775 which spans the period of Smeathman's voyage.

In the eighteenth and early nineteenth centuries it was no uncommon thing for wealthy patrons to send collectors abroad to enrich their collections. At that time the formation of private museums was more common than it is today. Many of these subsequently became part of the British Museum, where they are still available for the student to consult. It may be added in passing that strange objects often found their way into such private collections as, for example, the so-called " mermaids," for which large prices were paid. It was not till later that such specimens were proved to be the production of ingenious sailors. It is obvious that Smeathman left England to collect for his " Subscribers " Dru Drury, John Fothergill, Marmaduke Tunstall, Joseph Banks, and, later, the Dowager Duchess of Portland. Drury acted as a sort of Secretary to the venture and conducted all the correspondence with Smeathman. It is this correspondence which has produced the greater part of my information. Dr. John Fothergill, a Quaker, was a very successful medical practitioner who lived from 1712 to 1780, and among other interests maintained a world-famous botanic garden in which he raised many plants and trees not previously grown in this country. He maintained a correspondence with naturalists throughout the world, especially with America, which country he visited. He was a great philanthropist and by reason of his connection with the Friends, played an active part in the negotiations which led to the end of the personal proprietorship of Pennsylvania. In addition he was asked by the Colonists to intercede in the attempts made to prevent the war between America and the mother country. He was known personally to Benjamin Franklin. The full story of his life is told in R. H. Fox's book *Dr. John Fothergill and his friends* published in 1919.

Marmaduke Tunstall, who lived from 1743 to 1790, formed a large museum, chiefly of birds, which was sometime known as the Tunstall Museum and now forms part of the Museum of the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne. His best-known work is the rare *Ornithologia Britannica*, a folio of 6 pages first published in 1771 and re-issued as a facsimile by the Willughby Society in 1880. The work contains the first description of some of our British Birds.

Sir Joseph Banks, who lived from 1743 to 1820, was for many years President of the Royal Society. He was a great collector and formed a famous library the catalogue of which is still in constant use as a bibliographical tool. He played an active part in the early history of Australia, which he visited with Captain Cook. Fuller details of his life are to be found in Maiden, 1909, *Sir Joseph Banks : the Father of Australia.*

The Dowager Duchess of Portland (Margaret Cavendish Bentinck) formed a great private museum, including especially Mollusca. The contents were sold by auction in 1786 at a sale which lasted 38 days. She became one of Smeathman's subscribers in 1773.

These then were the patrons for whom Smeathman went to Africa to collect specimens.

The first mention of the scheme is in Drury's letter to Smeathman of 23.vii. 1771, which does no more than refer to the offer of help from " Mr. Tiese " which had been obtained by Fothergill. It seems that the initial subscription was £100 from each subscriber; a further subscription of £30 was made in 1773 when the Duchess of Portland, who paid both subscriptions, joined the scheme. In return for this payment Smeathman was to send home collections of insects, birds, plants, seeds, shells and the like and these were to be divided among the subscribers until each had received a sufficient return for his or her payment. A further 10 guineas was paid later in 1773.

So far as I can discover, Smeathman departed either late in 1771 or early in 1772 and originally he undertook to collect only for Drury, Fothergill and Tunstall, for on 21.viii.1771 Drury wrote : " When ye subscribers have all agreed on ye principal Articles of the Division nothing will obstruct your immediate preparation. Last Thursday I was with Dr Solander & Mr Banks when *you* was ye subject of our conversation. Mr Banks seemed heartily willing to join with your subscribers & therefore must be waited on when you come to town." Obviously Banks was duly " waited on " and agreed to join the subscribers. The next mention of the voyage is in Drury's letter of 1.iii.1772, by which time Smeathman had obviously reached Africa. It is addressed to "Sierra Leon Banee Island " and is a long letter, which shows clearly how friendly Drury and Smeathman were. Drury is quick to express the hope that " Seasoning " is successfully passed, for this he regarded as Smeathman's greatest danger. " The peril of encountering wild beasts & the *Baboons* wh. Dr. Tiese's friend told us off," he wrote, " I consider in a very different light from ye other; these may be overcome by courage skill and cunning." He then gave a little advice to his friend " . . . let me have none of your damned large scrambling characters that wont allow you to put above 6 words in a line . . ." Drury wrote a small, legible, hand.

A month later Drury had received 2 letters from Smeathman and in acknowledging them is somewhat sarcastic. " You will make a fine F.R.S. truly to stuff your letters with variations of ye wind, ye needles, latitude &c when you should be describing some of Nature's Beauties out of the three Kingdoms." Smeathman was not, however, despite his meteorological observations, elected a Fellow of the Royal Society, but the letter is interesting, and went on to

describe a visit made by the Duchess of Portland to Drury's collection of insects. The visit, which lasted some hours, pleased the Duchess and she expressed her hope that she might be able to acquire some of the duplicates Smeathman would doubtless be sending home. This was obviously the origin of her joining the subscribers. The next part of the letter is amusing. Drury related that he had been commissioned to paint some pictures for Madame Schwellenburg, one of the Queen's ladies and, as a result, had been appointed Goldsmith to the Queen. In telling this to Smeathman, Drury's pen wandered and he wrote : " Lord how I should rejoyce to see him [Smeathman] made *Butterfly catcher* to the Queen ! Risum tenealis ? But softly Dru where are you rambling to get firm upon the first step before you attempt to mount the second. True so I will; & therefore I will stop here." But stop he did not ! Having proceeded to describe the many visitors to his collection he wrote : " I might have many opportunities of obliging them with some Duplicates & as I have my business and interest to pursue might establish and extend both by this means if therefore you could send me a parcel of perfect ones by a private ship I should be exceeding glad it would be very beneficial to me many ways the amount you should direct me who to pay it to, but in doing this you must be secret, nor would I wish to have many scarce ones that you send to your subscribers common ones would answer very well if they differed from what have been hitherto received from China &c." I find this a somewhat remarkable suggestion for Drury to make, more especially as he was one of the subscribers, but it proved acceptable to Smeathman, for Drury wrote on 28.i.1773 : " I am glad you appr̊ove the hint I gave you of sending a private Box to England believe me it may turn out to yr advantage. It may—It will." In due course the specimens arrived and on 30.xi.1773, by which time only one small parcel had reached the subscribers, Drury wrote to tell Smeathman that he had already sold some £20 worth and he hoped to dispose of the remainder, possibly in Holland. Eventually the insects realised £42 6s. 0d. as follows : Revd. Mr. Wickham £15 6s., Henry Seymour £12 6s., — Sepp, of Amsterdam, £14 14s.

Possibly encouraged by this success, Smeathman soon proposed to start trading for rice along the coast, but to do this obviously a boat was necessary and request was made for one to be provided. Drury was nervous of the suggestion and advised his correspondent to proceed very slowly and only after careful consideration. Above all, great care must be taken to ensure that the subscribers heard nothing of the scheme. The suggestion of the boat was received favourably, however, and it was proposed to buy a suitable vessel in England and send it out to Smeathman. Drury in his letter of 30.xi.1773 promised to press the matter with the Secretary of the Admiralty but apparently no success resulted. This was possibly due to a disagreement between Banks and the Government at that time, for it is unlikely that Drury intended to make the appeal by means other than Banks' mediation. Drury next raised the matter at a meeting of the subscribers but Banks objected to the proposal and expressed the view that the provision of a boat for Smeathman would invite a wandering and rambling disposition and should be discouraged. Smeathman's brother, meanwhile, had been making enquiries and thought it would be best to buy a boat " with a cabin and deck " in London and send it out to his brother in Africa. This he estimated would cost £15 to £20. But this scheme like the others came to nothing, and Drury next suggested that goods should be sent out to Africa which Smeathman could sell and with the proceeds purchase a craft suitable for his purpose. He was advised that a 10-ton boat would cost some £60 in London and that the expense of sending it to Africa would cost a similar sum. In an attempt to get matters moving, Drury gave Smeathman authority

to draw on him up to £25 at not less than 28 days. Still no result was obtained and the final proposition came from Fothergill in a special letter which he wrote to Smeathman and which Drury forwarded on 4.i.1774. Fothergill's suggestion was for the immediate return of Smeathman to England, even if that necessitated chartering a special vessel for the purpose. A boat would then be fitted out to suit Smeathman's requirements and he could go to Africa until the onset of the rains and then return to England. The appeal had no effect, however, and on 22.xi.1775 a last effort was made to get Smeathman to come home. By this time Fothergill's scheme for the provision of a boat had received the blessing of his fellow-subscribers, stress being laid on the fact that times were especially propitious, since many vessels were laid up at Liverpool because of the disturbances in America. But nothing happened and Smeathman eventually went to the West Indies and, so far as I am aware, never returned to Africa.

The subscribers received many complaints from Smeathman, but the immense difficulties under which he worked must be borne in mind. The long delay in correspondence, due to boats returning from Africa via the West Indies, the primitive conditions under which he doubtless lived and worked and perhaps above all the climate generally all tended to make life unbearable. On the other hand, the subscribers were mainly interested in the receipt of collections and none arrived. Drury, when writing on 20.xi.1772, while sympathetic to Smeathman's complaints at the housing conditions under which he had to live, found himself forced to remind Smeathman that the subscribers had so far received no specimens in return for the money they had paid and were somewhat understandably restive on that account. As an instance of the adverse effect that Smeathman's conduct was having on his reputation, he added that Fothergill had proposed at a recent meeting of the subscribers that an additional payment of £50 should be made by each subscriber but the suggestion had been turned down until some return on the original payment should be forthcoming.

Another of Smeathman's complaints was the lack of sufficient assistance. His request for help was considered by the subscribers, and Fothergill offered to pay the expenses of a young Swede who was prepared to go to Africa, but the matter fell through, and Drury put forward the claims of a young man who wished to become an entomologist and who was prepared to go to Africa for 3 years at a salary of £20 per annum with all found. When interviewed by Smeathman's brother, however, this candidate was found to be unsuitable. Finally it was proposed to send a certain " Young Allen," but this came to nothing since Smeathman had left Africa before negotiations were completed. So far as I can gather from the correspondence, Smeathman must have had an assistant, named David Hill, for in his letter of 28.xi.1774 Drury reports that he had paid Mrs. Hill 5 guineas and given her a bill for £20 at 2 months on account of wages due to her son of that name, and a year later Drury wrote to Smeathman that he had met drafts of £30 and £20 in favour of Hill and reminding him of the payments he had himself made to the same person. Judging by the proposed wages offered to " Young Allen," this total payment of £76 5s. for wages must have covered a considerable period and a remark by Drury in his last letter to Smeathman that Hill had said that Smeathman still had a collection of insects in Jamaica suggests that Hill had remained in Africa until Smeathman's departure and possibly returned to England with the collections.

In due course the first consignment of specimens reached the subscribers. It was a box of insects acknowledged by Drury, nearly 2 years after Smeathman's departure, on 7.vi.1773. The contents of the box were valued by Messrs. Hudson, Church and Yeats at 80 guineas and after division the subscribers balloted for the insects. Smeathman soon objected that the valuation was too

low but Drury defended it in his letter of 30.i.1774.   Apparently some of the
specimens had travelled badly, for Drury complained of the condition of many
on their arrival and added : "... I charge you never use any of those cussed
small pins again.", for, he adds, the effect of the salt water on the pins had been
catastrophic !

The next consignment comprised 2 boxes, also of insects it seems, and with
these Smeathman included his own valuation of £200, which Drury felt was
much too high.   Moreover, Drury complained, the collection contained a high
percentage of duplicates of species already sent in the first despatch.

The third consignment was acknowledged by Drury in January 1774 and
was valued at £100, excluding the duplicates, some of which Drury had sold
for £28.   A difference of opinion seems to have arisen over these duplicates, for
Smeathman appears to have regarded them as still his property if the subscribers
did not wish to retain them and he asked for their return.   Eventually the
subscribers decided that all duplicates were their property and ordered them
to be sold.   This consignment realised 84 guineas as Drury reported in his
letter on 1.ii.1774.

The final collection arrived in 1775 but in the meantime on 26.v.1774 Drury
had had cause to complain bitterly to Smeathman that Fothergill was intensely
annoyed over a letter he had received from Linnaeus reporting that he had
received a fine collection of plants from Smeathman.   All the plants were new,
and Linnaeus asked that further specimens should be sent him.   It is not sur-
prising that Fothergill's remarks are stated to have been very much to the point,
for it should be remembered that Fothergill was passionately interested in
plants and seeds and had so far received none of these from Smeathman.

However, it appears that Fothergill's desires were satisfied by the tremen-
dous collection Smeathman eventually sent home, for the arrival of the collec-
tion created a major problem for Drury and he was forced to hire a room in
Essex House at a guinea a week to house it, so great was its bulk.   His letter
is dated 22.xi.1775 and addressed :   " To Mr Henry Smeathman at the Honble
Peter Campbell's Mount Pleasant Tobago or at Wm Moores junr Esq. Bridge
Town Barbadoes."   It is evident from the contents that Smeathman had left
Africa and despatched the whole of his accumulated collections to England.
Drury was alarmed at their size.   " My house could not possibly contain one
half the things when taken out of their packages." he wrote, and as for the un-
packing of the plants alone " the labour appears to me [to] be immense & I dare
say would take any single person 2 month to perform it, let the application be
as close as it may."   Drury complained at length that the collection should
have been sent in smaller consignments from time to time and not accumulated
as it had been.   Moreover, it is apparent that the subscribers were in no very
good temper with the results of the expedition for, Drury continued, " You
say ' you hope yr Patrons will advance what will be *necessary* ' I do not know
what that may be, but this I know that if nobody advances any more money
for you than them I believe your affairs will not be in a very flourishing con-
dition.—I have been informed that they are not extraordinary well satisfied
with what you have sent.—The Duchess has been continually teesing me about
Shells.—Mr. Tunstall has often spoke to me about *Birds*—& Mr Banks tells me
that you have wrote him an angry letter for not directing you how to collect
Plants, when he could not have been certain he says you would have collected
any, if he had given you those directions having not seen any produce of your
labour that way.—Dr Fothergill says little but much to ye purpose, but blames
you much for not sending during the 4 years one single box of Seeds.   In short
I believe if ye Drs. Scheme proves abortive, you will never set foot on the

African Shore again on any expedition for natural History." Hardly an
encouraging finale to some 4 years of grave discomfort and endeavour under the
African sun !

But this was not all the bad news, for it appears that Smeathman had
despatched some termite nests to England and Drury wrote : " However hard
and compact the Nests of the Bug a Bug [termite] may be in Africa they are
now so fragile and tender that every one of them broke to pieces—there is not
one whole piece and they all moulder to dust with amazing rapidity—I fear the
freight of them amounts to more money (considerably) than all the whole bulk
of them will fetch." It was a sad happening, for in those early days who knows
but that a termite's nest might have been an object of great value ! The news
of the remainder of the collection was better : " The insects are in fair condition
in general; all the shells appear to me to be *dead* but I do not understand that
branch——." Great surprise is expressed by Drury that so few birds were sent
and those sent were seemingly valueless, for John Latham valued them at less
than five shillings ! Smeathman had made an estimate of £200 for the insects
but, as usual, Drury thought this far too high and gave his opinion that a figure
nearer one-half that sum would more truly represent their value. Finally there
is evidence that the secret trade in duplicates was still proceeding, for Drury
wrote : " I shall also observe your directions about the Duplicates, not a Soul
has seen ym beside myself nor shall any one."

And there the correspondence ended. The final disposition of the great
collection is not recorded. I suppose it was duly divided among the subscribers
and the episode of the African expedition completed. There remains to relate
a few matters of more general interest in the letters such as Drury's advice to
search for gold. " Minerals or maybe mines may be found, where does all the
Gold come from that is brought to Europe ? sure there must be some source
or store of it from whence it is washed down into rivers and is this store never
to be discovered ? . . . how I should rejoyce if it was at ye last hour of my life
to know you had found it out. I verily believe it would drive the grim Tyrant
away and stop ye course of nature for a few minutes." Perhaps Drury was of
a mercenary nature, for in another letter he complained of the hard times and
the deadness of trade. " Oh damned Avarice," he wrote in 1773, " what a
large portion of ease & comfort have I parted with ? and entirely for the sake of
a son, who perhaps by and by it may be of no service to . . . To speak the
truth, that practice wch I observed early in life made me a Misanthropist."
But he controlled his feelings and continued : " I have lately heard that
Emeralds are frequently found there [in Africa]. If you therefore find any
green Stones pray send them to me." and in a later letter he asked for any
stones that are " quite black and hard preserve them with great care—they
must be blacker than flints and without any milky spots on them but of a
regular even colour." But poor Smeathman found no diamonds in Sierra
Leone !

That, then, is the story of the expedition to Africa. It is a story without an
end, for I have not discovered when Smeathman reached England again. That
he stayed some years in the West Indies is proved by a letter from Drury to
Gerald Tiese, who had claimed payment for a debt due from Smeathman.
Drury replied that he held no funds on Smeathman's account and added that he
had stayed in the West Indies much longer than was expected " or is good for
his reputation." That was written on 28.v.1777.

The remainder of Smeathman's story is briefly told, since little is known con-
cerning it. This is the more unfortunate, since that little is sufficient to whet
an appetite which at present I have no means of satisfying.

In Fox's *Fothergill*, 1919, page 213, it is recorded that " He [Fothergill] had, too, a cabinet of insects; on these he corresponded with Seymer : it contained many specimens from America. In order to investigate the natural history and products of Spain and the West Coast of Africa, Henry Smeathman was engaged in 1771 by Fothergill, acting in co-operation with Drury, Banks and Marmaduke Tunstall, to spend three years in those countries. Armed with Fothergill's instructions, Smeathman was enabled to survive the malignant fevers and fluxes of the Sierra Leone coast, although his companion in travel died. Large numbers of new plants were sent home by him to Banks—a beautiful passion-flower is named *Smeathmannia*—and many remarkable insects came to Fothergill. Smeathman's chief work was to write the first detailed account of the Termites or so-called white ants of Guinea, their habits, buildings and mode of propagation. It was a " traveller's tale " of no little wonder, for the ants dwelt in cities with towers; but the Royal Society gave it due hearing, and its truth has been established. The explorer allied himself by marriage with the native chiefs, and afterwards wandered to the West Indies, staying out long years beyond the time appointed; but his patron showed him much patience and liberality." Apparently the instructions given by Fothergill for the treatment of " fever " was with " an emetic, followed by cinchona in large quantities, given between the fits, and Epsom salts if necessary. In fluxes fowlbroth was to be taken largely, and after the bile had been freely discharged, anodynes."

It is a matter of regret that further details of Smeathman's alliance with the native chiefs are wanting and I am unable to find any word on this subject in addition to that quoted.

As I have stated already, Fothergill was a Quaker and medical man, and at his death John Coakley Lettsom succeeded to his practice. Lettsom was likewise a Quaker and also interested in natural history. According to Abraham (1933, *Lettsom his life, times, friends and descendants* : 236) Smeathman corresponded with Lettsom on the subject of balloons : " This . . . St Fond . . . was a man of many interests, for in the previous year he had written a treatise on balloons. He was evidently on friendly terms with Henry Smeathman, who at that time was writing from Paris to Lettsom on the same subject. Smeathman's name is now forgotten; but he actually discovered in this year the principle on which aeroplanes work, and had designed a machine to test his theories which had the approval of Franklin. Had petrol been known in his time, and had Smeathman lived, the whole of modern aeroplane construction might have been antedated by 100 years." I am of the opinion, however, that Smeathman was writing to Lettsom on a different matter, and Abraham's reference on page 57 of the same work is more probably concerned with the matters of common interest to Lettsom and Smeathman : namely, Smeathman's plan to settle free negroes in Sierra Leone, which proved a disastrous failure.

Some further information is to be found in Fox's *Fothergill* page 214 : " A copy of Smeathman's paper on the Termites, inscribed in his hand to Lettsom, is in the British Museum : at the end is a printed letter, in which he offers to teach elocution and polite literature in London; also a prospectus in French of a large work on his travels in Africa and America to be brought out by subscription—doubtless never published. In 1783 he was in Paris, his affairs being involved, and was occupied on the prevailing subject of balloons. He projected an aerostatic machine, and saw clearly that it must be heavier than air in order to obtain due control. He showed it to Franklin, who approved the principle. The Medical Society of London elected him a Corresponding Member in 1784. In 1786 Smeathman had another scheme, for forming a settlement

of Poor Blacks near Sierra Leone, in which he was supported by Jonas Hanway, Samuel Hoare and others, with a promise of assistance from the Commissioners of the Treasury. But he died before the party could set out; another leader, Irvine, was found, with surgeons, chaplain and others, Lettsom interesting himself in the venture. About 500 free negroes of both sexes, besides whites, set sail, but the expedition was doomed to failure from the outset : they quarrelled and fought on the passage : sickness played havoc among them : the leaders died, and soon most of the party perished in the tract of land they had purchased from " King Tom ". The white ants ate up the seeds and stores."

And so I come to the end of the story. For over 150 years Smeathman has been little known to entomologists and now he is stated to be forgotten even in name ! In Entomology his name will live if only by reason of his classic paper on the Termites. I think it will also continue to be known in those circles interested in the humanitarian principles for which our forefathers struggled so hard in their attempts to alleviate the lot of the slaves in the Sugar Plantations of the West Indies so long ago.

LARVAE OF THE BRITISH TRICHOPTERA. 1

By N. E. HICKIN, Ph.D., F.R.E.S.

Stenophyllax stellatus Curtis (LIMNOPHILIDAE).

DESCRIBED from larvae collected from Dowles, Worcestershire, some of which were reared to maturity and also compared with larvae collected from the Lake District (Grizedale Tarn).

In Dowles Brook (a fast-running stream) it is most abundant, sheltering in small groups under the slabs of Bunter sandstone which form the bed of the stream. There is no phanerogamic vegetation in this water.

The *Case* is about 20–22 mm. in length and is slightly curved longitudinally with slight dorso-ventral flattening. It is composed of small flattened pebbles and fragments of stone and large sand grains (fig. 1). Smaller pebbles and sand grains tend to be placed on the ventral surface of the case and the larger pieces of stone are placed at the sides near the ventral surface. There is a small opening at the posterior end, and, previous to pupation, the case is attached by the anterior end to the underside of a large stone. The *larva* is uniformly cylindrical with the head hypognathous (fig. 2). *Head :* the clypeus has a kite-shaped pattern of dark spots at the aboral end with a pair of large bristles at the base of the pattern. At the oral margin of the clypeus there is a row of six bristles, the outermost pair of bristles are just embraced by the outcurving of the clypeus. A pair of smaller bristles are situated between the latter and the former pair of bristles. The mouth-parts are very small compared with the size of the larva. The labrum (fig. 3) is strongly indented, the indentation being heavily sclerotised. A small blunt spine is situated at each end of the sclerotised part. A row of six bristles is located transversely in the middle of the exposed part of the labrum. The mandibles, which are slightly asymmetrical (fig. 4), are broad and heavily chitinised. There are four large teeth and two much smaller teeth. A tuft of hair is situated near the small teeth and directed inwards. The maxillae and labium (fig. 5) are extremely small. The maxillary palp is four-segmented and on the maxilla are several tufts of hairs and modified setae which are probably sense organs. On the oral side of the labium is a pair of spines, set on small protuberances, whilst on the ventral surface of the labium there is a pair of large spines as long as the labium itself, and projecting from a pair of sclerotised parts near the base (fig. 8). *Thorax :* the terga
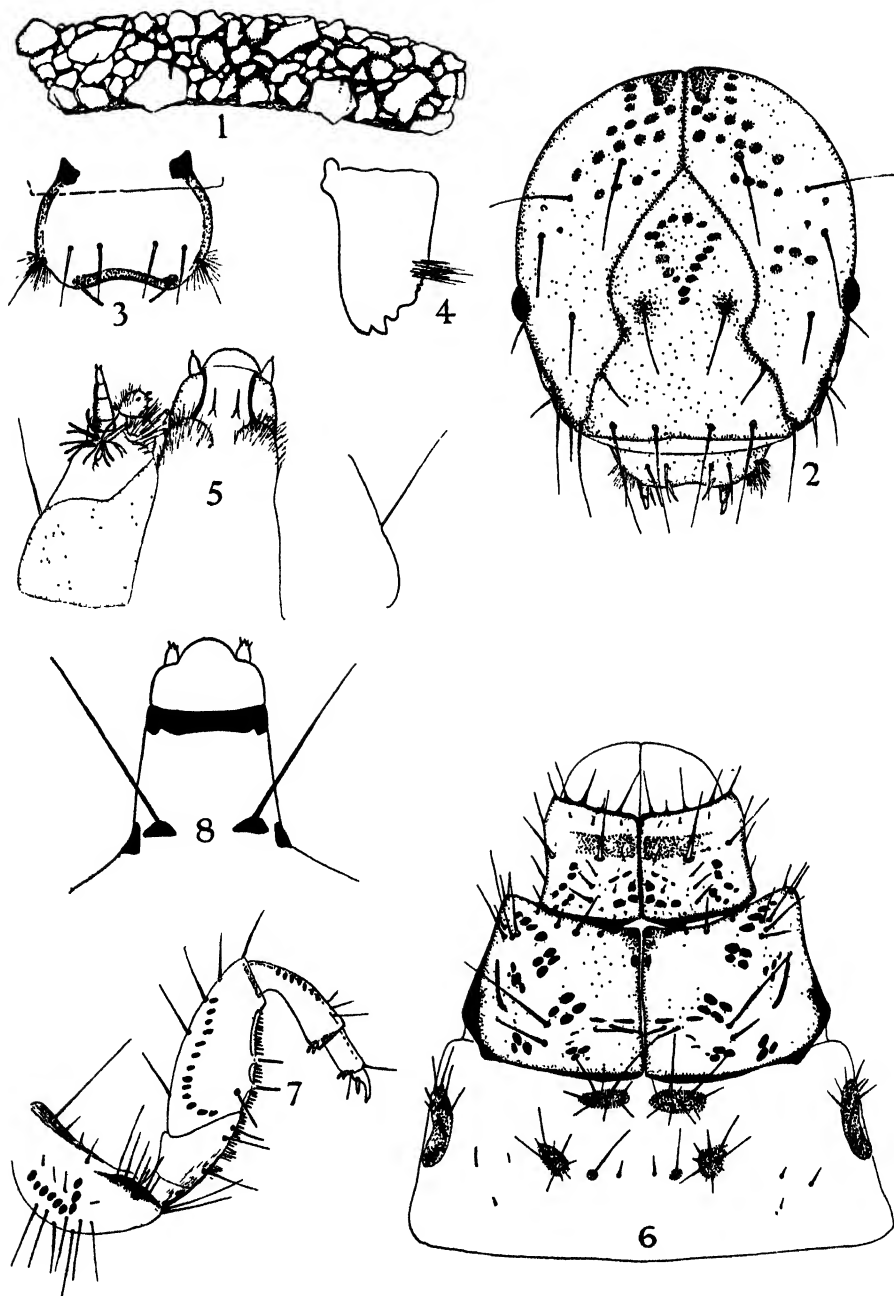
FIGS. 1–8.—*Stenophyllax stellatus*, 1, case. 2, head. 3, labrum. 4, right mandible. 5, labium and maxilla. 6, head and thorax. 7, prothoracic leg. 8, ventral view of labium.

of pro- and mesothorax are completely sclerotised whilst the metathoracic tergum is only partially sclerotised (fig. 6). A dark transverse band runs across the prothoracic tergum slightly nearer the anterior than the posterior margin. In dorsal view three patches of dark spots are visible, one medium and two lateral. All these are posterior to the dark transverse band. The mesothorax is almost half as wide again as the prothorax. Groups of dark spots are arranged obliquely running from the middle of the posterior margin to the lateral vertex of the anterior margin. Two isolated spots are situated one on each side of the median line close to the anterior margin. The posterior lateral vertices are heavily sclerotised. The metathorax is slightly wider than the mesothorax. It is unsclerotised except for isolated patches. On the dorsal surface two patches lie anteriorly near the median line. A number of stout bristles emerge from each patch. Posterior to the latter are two more patches of approximately similar size but lying farther away from the median line. These patches also are furnished with bristles. In between the latter patches is a pair of very small sclerotised patches each bearing a single bristle. A larger
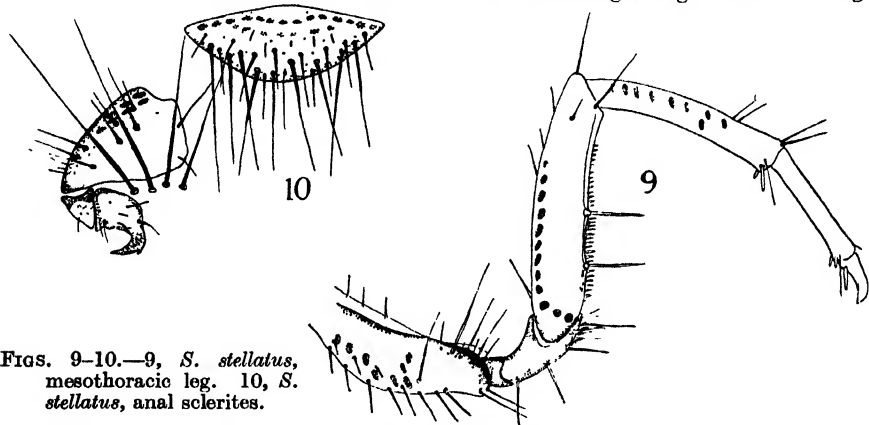
FIGS. 9–10.—9, *S. stellatus*, mesothoracic leg. 10, *S. stellatus*, anal sclerites.

sclerotised patch occupies the pleural regions of the segment. These patches bear a bunch of bristles anteriorly and in addition are marked by a short series of dark spots. A dark spot in the central part of the patch is elongated. *Legs :* the prothoracic legs (fig. 7) are approximately two-thirds the length of the mesothoracic legs (fig. 9), but are considerably broader. Meso- and metathoracic legs are approximately equal in length but mesothoracic legs are slightly broader. The most heavily sclerotised segment is the trochanter in each case. In all legs there are two distal spurs on the two segments of the tarsus and two marginal spurs on the tibia. A spine is present at the base of each claw. *Abdomen :* hooks on first abdominal segment are absent. Gills are present, but their position and numbers are variable, and thus have little value in identification. The abdominal claws are closely opposed to the last segment and are two-segmented. Four very stout bristles are situated between the claw and the lateral sclerite on each side (fig. 10). The superanal plate has the anterior margin of greater radius of curvature than the posterior margin. Along the latter there is a series of about nine large bristles and some smaller ones. Along the anterior margin there is a row of faintly marked spots indented in the centre and with a fainter and smaller row behind (fig. 10).

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# LARVAE OF THE BRITISH TRICHOPTERA. 2

By N. E. Hickin, Ph.D., F.R.E.S.

Triaenodes bicolor Curtis (Leptoceridae).

The larva of this species is very easily distinguished both morphologically and on account of its characteristic habit of swimming. It is able to propel itself with its case through the water by means of rapid movements of its meta-thoracic legs, which are especially adapted for the purpose. The following description of the larva is based on material collected at Clay Pond, Wray Castle, Windermere, and compared with specimens from a pool in Broadmoor Wood, Rubery, Worcestershire. Both these pools are still water and contain much phanerogamic vegetation.

Case (fig. 1): the case is long and tapering. It is composed of regularly shaped pieces of leaf or small whole leaves. All the fragments are arranged in a spiral whorl, the whole case being strongly reminiscent of a miniature *Phryganea grandis* case. Size up to 35·0 mm. in length, 2·0-2·5 mm. in width. *Larva :* the head is almost prognathous. A prominent feature of the larva is the length of the metathoracic " swimming " legs and their hair fringes. Size of larva 12·0-13·0 mm. long, 1·5 mm. broad. *Head* (fig. 2): very bright golden yellow marked with prominent dark spots. Two dark bands run longitudinally along the clypeus in which some of the dark spots are confluent. The dark bands are united posteriorly by a transverse band of four dark spots. A larger but similar shaped pair of dark bands runs parallel to the first-mentioned bands just outside the clypeus. Other patches of dark spots occur on the genae, and four large spots lie between the four trans-verse spots on the clypeus and the larger pair of dark bands where they run together. The antennae are two-segmented. The proximal segment is bulbous, whilst the distal segment is long, slightly incurved and surmounted with a strong bristle (fig. 8). *Mouth-parts :* the mandibles (fig. 3) are asymmetrical. The maxillary palps are 3-segmented, whilst the ligula is broad. The single-segmented labial palps are very small. All the mouth-parts are very small in comparison with the size of the larva. The labrum is notched, the concavity being sclerotised (fig. 4). *Thorax* (fig. 2): pro- and mesothorax strongly sclerotised, deep golden yellow in colour and marked with prominent dark spots. Metathorax unsclerotised but with long dark coxal sclerites with which the swimming legs articulate. The prothorax has patches of dark spots situated along the posterior margin. Several stout bristles are placed on the anterior angles of the segment. In the mesothorax a short row of dark spots lies along the anterior margin, together with a row of about six long stout bristles. In addition a transverse row of spots lies across the middle of the segment and divides into two a little way from the median line. *Legs :* prothoracic legs short and broad. Femur has three marginal spines and the trochanter four. Tarsal seg-ments short, proximal segment very broad (fig. 5). Metathoracic legs long with two rows of hairs running along whole length (fig. 6). *Abdomen :* dorsal and lateral hooks present on first segment of the abdomen. Single gills are usually present on the dorso-lateral and ventro-lateral surfaces of segments II to VII on each side but those on the last two segments may be absent. On the dorsal surface of segment IX there is a dark-coloured heart-shaped anal sclerite. It does not bear bristles (fig. 7).

Larvae of *Triaenodes conspersa* Rambur, the only other species in the genus on the British list, and the only species with which *T. bicolor* could be confused, have not yet been collected by me. Ulmer states, however, that the head is brownish without dark spots and the larva is also larger than *T. bicolor*.
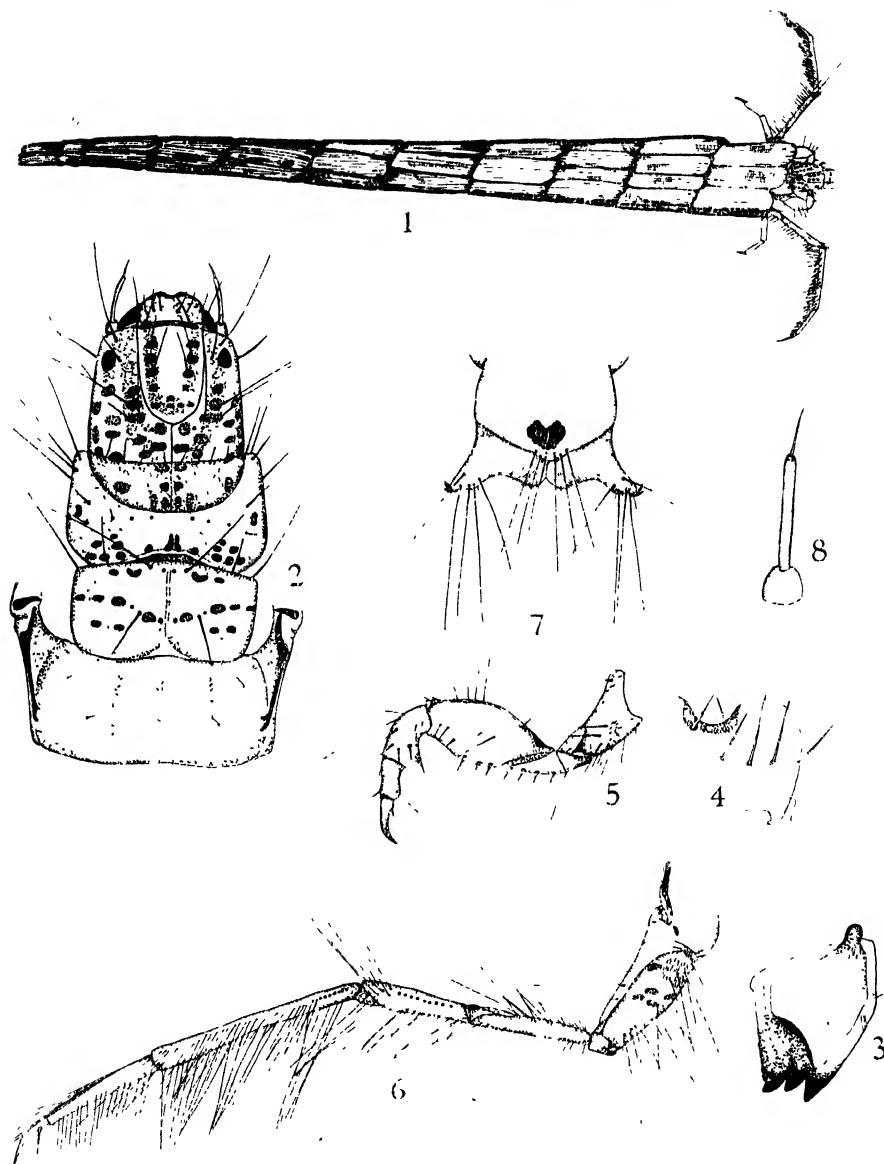
FIGS. 1–8.—1, *Triaenodes bicolor*, larva in case. 2, *T. bicolor*, head and thorax. 3, *T. bicolor*, mandible. 4, *T. bicolor*, labrum. 5, *T. bicolor*, prothoracic leg. 6, *T. bicolor*, metathoracic leg. 7, *T. bicolor*, anal segments. 8, *T. bicolor*, antenna.

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——, 1909, *Süsswasserfauna Deutschlands* **5, 6** : 249.

LARVAE OF THE BRITISH TRICHOPTERA. 3

By N. E. HICKIN, Ph.D., F.R.E.S.

Rhyacophila dorsalis Curtis (RHYACOPHILIDAE).

THIS species is commonly found crawling about on the under-surface of stones at the bottom of quickly running streams and brooks. The following description was made from specimens taken from Dowles Brook, Bewdley, and compared with specimens from Cranham, Gloucestershire.
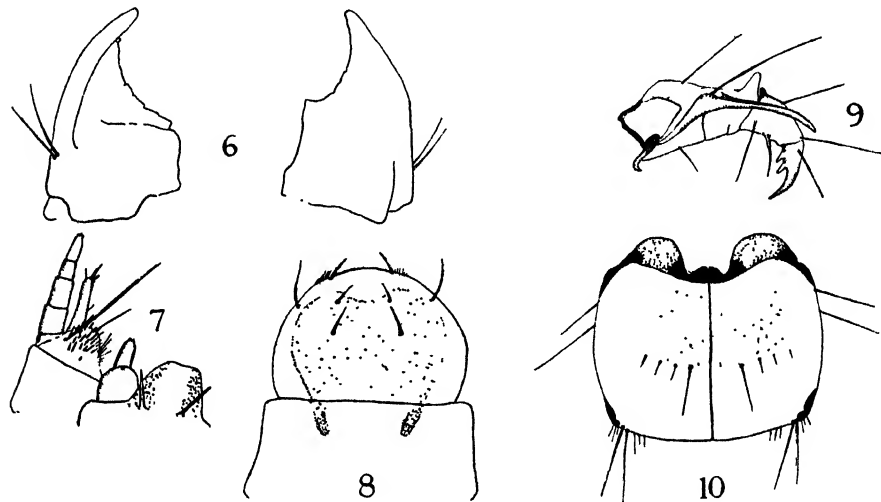
FIGS. 6–10.—6, *R. dorsalis*, mandibles. 7, *R. dorsalis*, maxilla and labium. 8, *R. dorsalis*, labrum. 9, *R. dorsalis*, anal claw. 10, *R. dorsalis*, prothorax.

Larva (fig. 1): campodeiform. Head procentrous. Only the prothorax is sclerotised. Gills present. The head and prothorax is a light creamy yellow, the remainder of the thorax and the abdomen varies from light green to purplish shades. *Head* (fig. 2): very long with the genae running parallel for a considerable distance. The oral part of the clypeus is attenuated. At the aboral end of the clypeus is an inverted heart-shaped dark marking occupying almost all of the area. A dark patch also occurs on each of the genae near the suture. *Mandibles* (fig. 6): asymmetrical. Each bears a pair of bristles, but the left has a prominent ridge a short distance from the outer border. *Labrum* (fig. 8): almost hemispherical. The central part is sclerotised, and shows a median notch opposite the anterior margin. Apart from two pairs of bristles situated on the margin there are two other pairs in two transverse groups. The maxillary palp has the appearance of being five-segmented, but the proximal segment is very short. A one-segmented palpiform mala is present. *Labium* (fig.7): very small. *Thorax:* only the prothorax is sclerotised. The posterior and lateral margins of the prothorax (fig. 10) are convex. The anterior margin is concave with two large outer and two small inner articulating facets which are heavily sclerotised and dark in colour. The outer angles between the posterior and lateral margins of the prothorax, from which two large and several smaller bristles arise, are also more heavily sclerotised and dark in colour. A group of eight bristles form a transverse band across the centre of the prothorax and from it
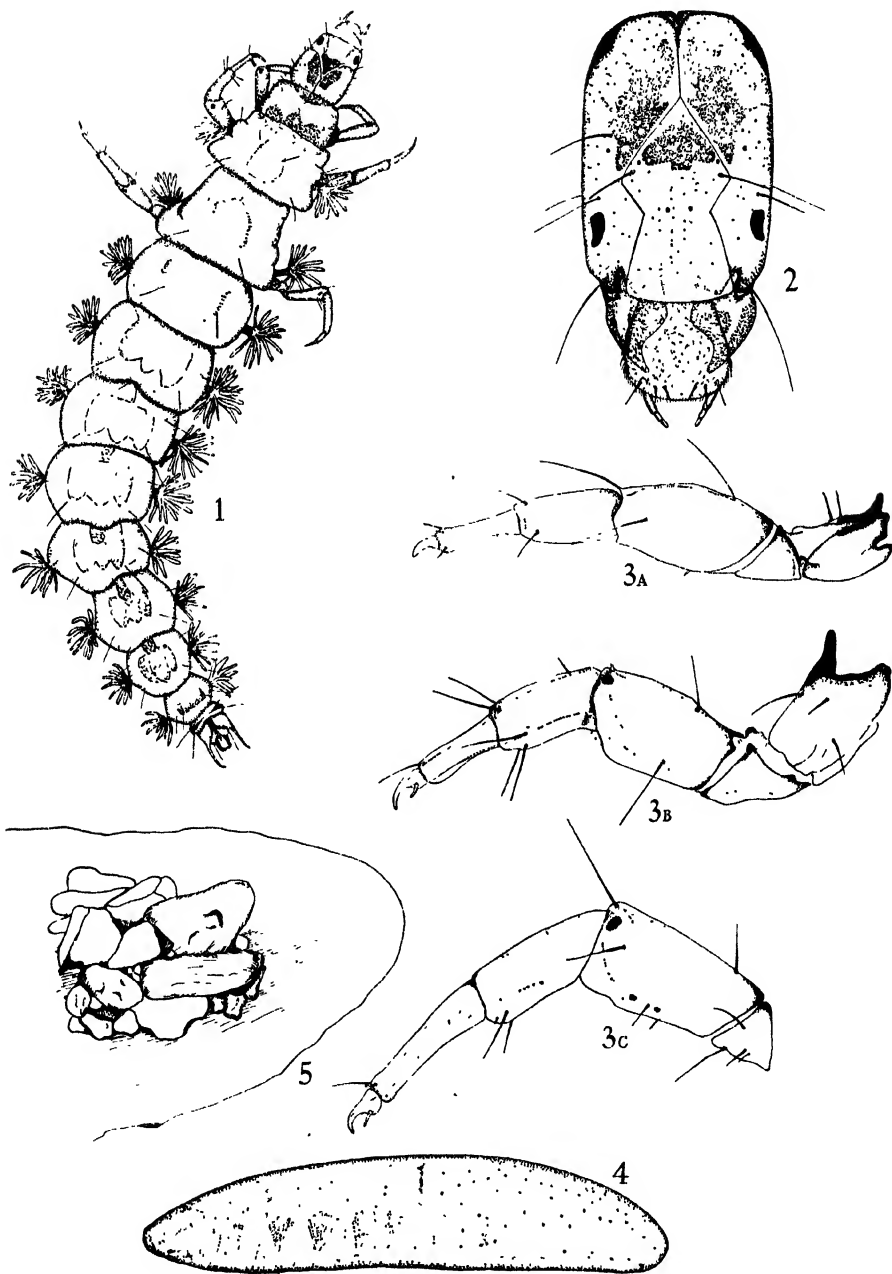
Figs. 1–5.—1, *Rhyacophila dorsalis*, larva. 2, *R. dorsalis*, head. 3, *R. dorsalis*, A prothoracic leg, B mesothoracic leg, C metathoracic leg. 4, *R. dorsalis*, cocoon. 5, *R. dorsalis*, pupal case.

stretching to the anterior margin of the prothorax is a dark patch. *Legs* (fig. 3) : comparatively short and stumpy. Approximately all the same size. Tarsal claws small with a small spur in the meso- and metathoracic legs. Trochanter is one-segmented. No spines on ventral margin of tarsus and tibia. Three bristles occur on ventral surface distal end of proximal tarsal segment in meso- and metathoracic legs. A dark spot occurs on each side of the tibia at the distal end near the dorsal surface in meso- and metathoracic legs. A tuft of gills occurs at the bases of meso- and metathoracic legs. *Abdomen :* the width of the abdominal segments decreases progressively from anterior to the posterior end. Each of the first eight segments bears a large filamentous tuft of gills and four bristles on the dorsal surface. Each segment is strongly convex in dorsal and lateral regions. The ninth segment has no gills and has a dark heavily sclerotised transverse band in a median position. The anal hooks (fig. 9) are two-segmented and long. The proximal segment bears a long bristle and the distal segment several smaller bristles and spines. Auxiliary hooks are present external to the main hooks but are one-segmented. *Pupation :* just before pupation the larva constructs a chamber of large fragments of stone which it lines with silk (fig. 5). A tough chestnut-coloured pupal case or cocoon (fig. 4) is formed in which the larva pupates.

<div align="center">REFERENCE.</div>

MOSELY, M. E., 1939, *British Caddis Flies* : 238.

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LARVAE OF THE BRITISH TRICHOPTERA. 4

By N. E. HICKIN, Ph.D., F.R.E.S.

Philopotamus montanus Donovan (PHILOPOTAMIDAE).
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THE present description is taken from specimens collected in Lily bed stream running into the west side of Lake Windermere. This stream cascades over a bed of rocks and is very well aerated. The larva constructs silken nets and tunnels on the underside of the pieces of rock in the torrential part of the stream.

The larva is campodeiform and has the head and prothorax a light chestnut-brown colour. Only the prothorax is sclerotised. The abdomen is white and lateral abdominal gills are absent. In size the larvae go up to 22·0 mm. long and 2·6 mm. broad, but maximum size is variable. *Head :* the head is long, the genae running parallel for some considerable distance. It is prognathous. There are no dark spots, the colour being a uniform light chestnut brown, except at the anterior margins of genae and clypeus, which are more heavily sclerotised and very much darker in colour (almost black). The anterior part of the clypeus is attenuate (fig. 1). The antennae are rudimentary. *Mouth-parts :* the labrum is quite distinctive (fig. 2). It is unsclerotised and extends a considerable distance forwards. Right and left lobes form brushes with straight anterior margins which are transverse. The brushes consist of several rows of small hairs with a bunch of longer hairs at the sides curling inwards. The mandibles have the outer margin uniformly convex with two projecting bristles arising at about the middle. The outer tooth is much larger than the others. The mandible is more than twice as long as broad (fig. 3). The maxillae have four-segmented palps with a bristle towards the base (fig. 4). The maxillae are beset with a number of thin sickle-shaped bristles all bearing secondary hairs (fig. 4, A). All these bristles are directed inwards towards the labium. The latter is very small, rather hairy, and the labial palps are much reduced. *Thorax :* only the prothorax is sclerotised. It is light chestnut brown in colour, except the posterior margin, which is more heavily sclerotised and is much darker in colour. A row of bristles is set along the anterior margin of the prothorax and another row runs transversely across the centre. *Legs :* the tarsal claws of all the legs

have a spine set upon a protuberance. The protuberance is elongated beyond the base of the spine, this being shown better in the meso- and metathoracic legs than in the prothoracic. The tarsal segment is fringed with small spines along its entire length in the prothoracic leg (fig. 5), but these are restricted to the distal end of the segment in the meso- and metathoracic legs. A small group of spines on the distal end of the tibia are somewhat flattened. *Abdomen:* the abdomen, which is white in colour, is devoid of gills except a small group just dorsal to the anus. These are apparently eversible. The abdominal claws are two-segmented, the proximal segment being slightly concave anteriorly and beset with three spines. The claw has a small group of hairs on the convex side.
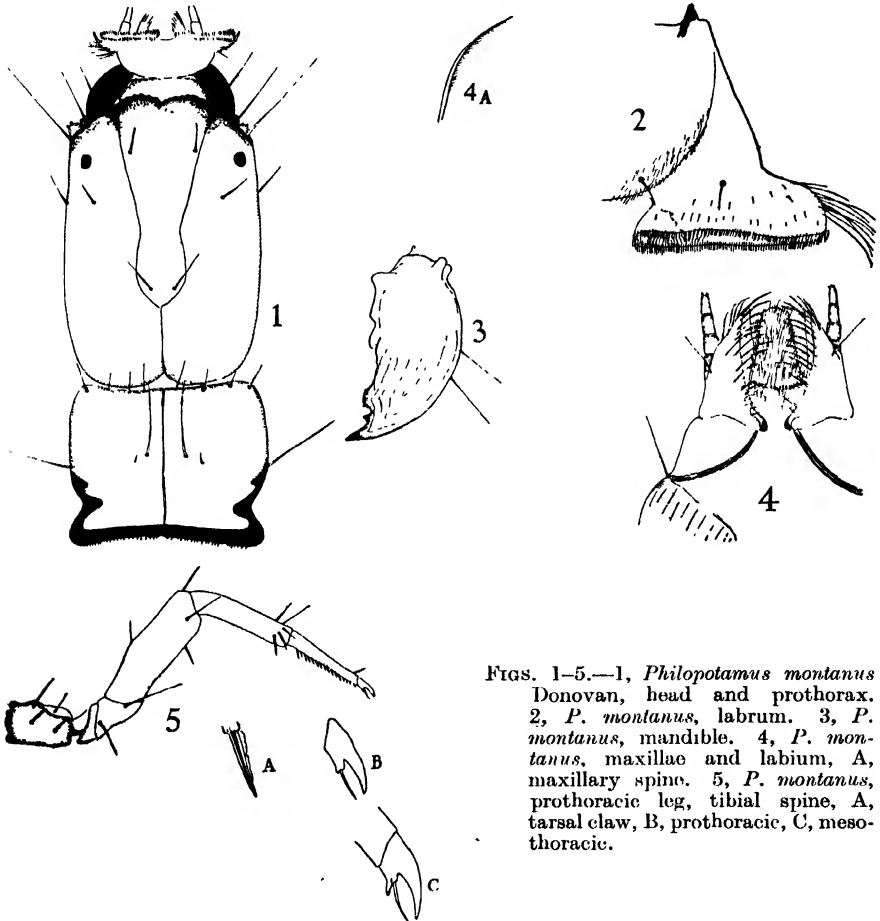
FIGS. 1–5.—1, *Philopotamus montanus* Donovan, head and prothorax. 2, *P. montanus,* labrum. 3, *P. montanus,* mandible. 4, *P. montanus,* maxillae and labium, A, maxillary spine. 5, *P. montanus,* prothoracic leg, tibial spine, A, tarsal claw, B, prothoracic, C, mesothoracic.

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A NOTE ON *TIMULLA (TIMULLA) ERIPHYLA* MICKEL (HYM., MUTILLIDAE), A PARASITE OF *TACHYSPHEX BLATTICIDUS* F. X. WILLIAMS (HYM., LARRIDAE), FROM TRINIDAD, B.W.I.

By E. McC. CALLAN, Ph.D., F.R.E.S.

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THE host relations of the neotropical MUTILLIDAE appear to be little known. Mickel (1938 : 536), referring to the genus *Timulla*, states that "nothing is known regarding the biology or the hosts of any of the neotropical species." This is the more remarkable in that Mickel refers to no fewer than 175 species of this genus from the neotropical region.

The Mutillid, *Timulla (Timulla) eriphyla* Mickel, was reared as a parasite of the Larrid, *Tachysphex blatticidus* F. X. Williams (1941), at St. Augustine, Trinidad, B.W.I. This record is of interest, therefore, as a first contribution towards a knowledge of the biology and host relations of the neotropical species of *Timulla*.

The LARRIDAE include burrowing wasps, the majority of which provision their nests with Orthoptera, although some are known to prey on Hemiptera and Psocoptera. *Tachysphex blatticidus* is a small black species, nesting gregariously in sandy places, and preying on cockroaches, with which it provisions its nests.

The cockroach prey is captured in the adult stage, and Mr. J. A. G. Rehn, who has very kindly examined specimens, informs me (1940, *in litt.*) that it is a *Chorisoneura* sp. Mr. Rehn states that the genus *Chorisoneura* includes a large number of species, separated often by genitalic and venational characters, and unless the material is in perfect condition, its determination is almost or quite impossible. Unfortunately the condition of the cockroach prey was such that it was impossible to make a specific determination.

Mickel (1938) described the female of *Timulla eriphyla* from French Guiana with paratypes from French Guiana; Trinidad, B.W.I.; Venezuela and Colombia. The male is unknown.

In July 1938, *Tachysphex blatticidus* was found nesting gregariously at St. Augustine, Trinidad, B.W.I., and a number of cocoons were removed from the nests. Larvae in various stages of development were also found feeding on their cockroach prey. Some of these completed their development and pupated, wasps eventually emerging from the cocoons. From cocoons removed from nests, three females of *T. eriphyla* emerged on 4, 6 and 9 August 1938 and a number of males and females of *T. blatticidus* on 15 August 1938.

One female of *T. eriphyla* has been deposited in the collection of the University of Minnesota and two females in the collection of the Imperial College of Tropical Agriculture, Trinidad, B.W.I. Williams (1941) refers to the museums and collections in which specimens of *T. blatticidus* have been deposited.

I wish to express my indebtedness to Professor C. E. Mickel of the University of Minnesota for the determination of *Timulla eriphyla*, Mr. J. A. G. Rehn of the Academy of Natural Sciences of Philadelphia for the determination of *Chorisoneura* sp., and Dr. F. X. Williams of the Hawaiian Sugar Planters' Association Experiment Station, Honolulu, Hawaii, who kindly undertook to describe *Tachysphex blatticidus* as a new species.

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THE RELATIVE SIZES OF DIFFERENT PARTS IN BEETLES OF THE GENUS *LAEMOPHLOEUS* (COLEOPT.: CUCUJIDAE)

By J. A. REID, B.Sc., A.R.C.S., F.R.E.S.

THE problem of the differential growth-rates of various parts of animals has been discussed by Huxley (1932). The differential growth-rates of the early stages result, of course, in different sizes of parts in the adult. To prove that an organ exhibits differential or relative growth, it is only necessary to show that its length or weight, or whatever property is measured, is greater (or smaller) with respect to the rest, or to some other part of the body, in large specimens than in small (see table II, column A/E). The degree of relative (differential) growth is measured by k which is the constant of differential growth ratio. Huxley (1932) gives the following formula, $y = bx^k$, where y is the differentially growing organ and x the standard dimension. If the formula is obeyed then, when the logarithms of the values of y and x are plotted, a straight line should be obtained; the tangent of the angle this line makes with the x axis $= k$. If there is no differential growth then the slope of the line is 45° and the value of $k = 1$; if there is positive differential growth, the value of k is greater than unity. If differential growth is negative; *i.e.*, the differentially growing organ becomes smaller relative to the standard dimension as the animal becomes larger, then k is less than unity.

For the purpose of making measurements, most of the *Laemophloeus* were taken from insectary cultures and were gummed on microscope slides with the antennae stretched out parallel to the long axis of the body. The measurements were made with a micrometer attached to a binocular microscope, and the length of the elytra was chosen as the standard dimension indicating the size of a specimen.

Table I records the observed extremes of body length, antennal length,

TABLE 1.

Observed range of body length, antennal length, and the ratio antennal length/body length.

Species of *Laemophloeus*		Body length, mm.	Antennal length, mm.	Ratio
minutus	♂	1·38–1·91	0·84–1·65	0·53–0·86
	♀	1·40–1·92	0·54–0·96	0·50–0·52
turcicus	♂	1·62–2·17	0·91–1·77	0·69–0·80
	♀	1·50–2·10	0·77–1·14	0·50–0·54
ferrugineus	♂	1·78–2·25	0·76–1·14	0·42–0·55
	♀	1·70–2·34	0·70–0·93	0·40–0·42
Sp. near to *ater* [1]	1 ♂	2·36	0·87	0·37
	3 ♀	1·86–2·28	0·75–0·84	0·36–0·40

[1] For the taxonomic account of these species see p. 29–33.

and the ratio antennal length/body length. The table serves to display the relative sizes of the species and the differences in the relative lengths of the antennae between the species and between the sexes. Only a few measure-

ments of total body length were made, so that the ranges recorded for the body length and the ratio are tentative only. Contrary to the statement by Richards and Herford (1930 : 370) in their key, the ratio shows that the antennae of male *minutus* and *turcicus* do not attain a length as great as or greater than that of the body.

Differential growth in L. turcicus *Grouvelle*.

Males. In a series of 58 specimens measurements were made of the length of the elytra, antennae, and last three segments of the antennae. The specimens were divided into six groups according to the length of the elytra, and table II shows the mean values of the length of the elytra, antennae, etc., in these groups. The figures in italics are the values of *C*, the coefficient of variability, which is the standard deviation expressed as a percentage of the

TABLE II.

Grouped data. Measurements in millimetres. The figures in *italics* are the values of *C*, the coefficient of variability.

Elytra length groups	No. of specimens per group	E. Mean elytra lengths	A. Mean antennal lengths	A/E	Means of last 3 antennal segments	Means of remainder of antennae
58 male turcicus.						
0·87–0·92	2	0·89 *11·94*	0·99 *10·29*	1·102 *11·15*	0·34 *8·93*	0·65 *11·14*
0·93–0·98	4	0·97 *4·67*	1·12 *11·20*	1·154 *10·30*	0·38 *15·15*	0·74 *18·30*
0·99–1·04	17	1·02 *3·50*	1·27 *8·69*	1·249 *6·85*	0·43 *10·82*	0·84 *9·52*
1·05–1·10	18	1·08 *2·28*	1·43 *9·87*	1·327 *8·08*	0·49 *11·02*	0·95 *6·60*
1·11–1·16	12	1·13 *4·80*	1·54 *11·45*	1·357 *10·02*	0·53 *9·15*	1·01 *7·60*
1·17–1·23	5	1·21 *1·36*	1·70 *3·82*	1·404 *4·26*	0·58 *13·10*	1·12 *5·15*
44 male minutus.						
0·78–0·83	4	0·79 *11·73*	0·89 *9·56*	1·126 *8·28*	0·29 *21·55*	0·61 *11·15*
0·84–0·89	12	0·86 *11·30*	1·09 *10·75*	1·261 *12·65*	0·37 *11·95*	0·71 *13·01*
0·90–0·95	11	0·92 *3·77*	1·28 *7·47*	1·384 *7·01*	0·44 *7·60*	0·84 *8·08*
0·96–1·01	9	0·98 *1·14*	1·45 *6·27*	1·479 *5·90*	0·52 *11·24*	0·94 *6·24*
1·02–1·08	8	1·04 *5·79*	1·56 *6·60*	1·490 *6·67*	0·56 *18·38*	1·00 *14·90*

mean. The column A/E gives the ratio mean antennal/mean elytra length and it will be seen that the ratio becomes steadily greater with increasing elytra length, demonstrating that the antennae exhibit positive differential growth. In arriving at the values of A/E, the ratio was calculated individually for each specimen and the group means then taken, so as to get a greater degree of accuracy than would result from dividing the means of the antennal lengths by those of the elytra. The ratios given in the other tables were calculated directly from the means of the antennal and elytral lengths, and the thorax widths, as the series of specimens are smaller and do not justify a greater degree of accuracy.

Fig. 1 is the graph obtained when the logarithms of the elytra length $= x$ are plotted against those of the antennal length $= y$. It will be seen that the points do not fall quite on a straight line, but form a very gentle sigmoid curve suggesting that the value of k is not constant, but rises to a maximum in specimens of medium size and then falls again in those of the largest size. The angle that the line makes with the x axis is $62 \cdot 5°$, which gives a value for k of $1 \cdot 92$. The length of the last three segments of the antennae was measured to discover whether there was what Huxley (1932) terms a growth gradient; that is to say, whether the rate of differential growth, as measured by k, was greater in one part of the antennae than in another. The logarithms of the values for the last three segments of the antennae, and for the remainder of the antennae, were plotted separately against those for the elytra, but the value of k was the same for both, $1 \cdot 88$, which means that there was no appreciable growth gradient between the last three segments of the antennae and the remainder. This was confirmed by plotting the values of the last three segments against those of the remainder, treating the latter as the standard dimension, x; the resulting line had a slope of exactly $45°$ ($k = 1$).

In another series of 27 males the width of the thorax was measured (see table IV). The logarithms of the mean values of the thorax widths were plotted against those of the elytra lengths as before, but the slope of the line did not depart significantly from $45°$, and it may be said that in this small series no differential growth of the thorax with respect to width was detected.

Females. In a series of 20 female *L. turcicus*, the length of the antennae and elytra and the width of the thorax were measured (table III). No differential growth of the antennae was detected, but the width of the thorax showed a definite negative differential growth with respect to the length of the elytra; the slope of the line was $39°$ ($k = 0 \cdot 81$).

Differential growth in L. minutus *Olivier.*

This species forms an interesting contrast to *turcicus*, for it displays a distinctly greater degree of differential growth in both sexes.

Males. In a series of 44 males (see table II) the same parts were measured as in the males of *turcicus*. Fig. 2, which corresponds to fig. 1, is the graph obtained when the logarithms of the mean antennal lengths are plotted against those of the elytra. The series was divided into five size groups, and it will be seen that while the first four points on the graph lie nearly on a straight line, the fifth is some way below this line. It is possible that the specimens with an elytra length of more than $1 \cdot 02$ mm. (see table II) have a value of k distinctly lower than that of smaller specimens. Huxley has found that a differentially growing organ may display two apparently disconnected growth curves each with a different value of k, and each value of k holding good over a certain part of the size range of the organ. Further data would be necessary

TABLE III.

Grouped data.   Measurements in millimetres.   The figures in *italics* are the values of C, the coefficient of variability.

E. Mean elytra lengths	No. of specimens per group	A. Mean antennal lengths	T. Mean thorax widths	A/E	T/E
— 20 male *ferrugineus*.					
1·00 *4·55*	4	0·85 *4·89*	0·49 *17·62*	0·850	0·494
1·04 *6·60*	5	0·91 *9·65*	0·52 *20·60*	0·874	0·500
1·11 *10·78*	5	0·99 *16·18*	0·56 *9·00*	0·891	0·507
1·18 *5·26*	6	1·06 *6·27*	0·60 *19·98*	0·894	0·507
20 female *turcicus*.					
0·93 *8·01*	5	0·85 *12·79*	0·43 *6·11*	0·910	0·464
1·00 *13·99*	5	0·88 *10·60*	0·46 *7·16*	0·885	0·464
1·05 *6·38*	5	0·94 *13·85*	0·48 *17·90*	0·896	0·457
1·19 *5·70*	5	1·07 *10·43*	0·53 *5·00*	0·899	0·447
20 female *minutus*.					
0·82 *23·10*	5	0·69 *19·05*	0·41 *25·28*	0·845	0·500
0·90 *16·05*	5	0·77 *7·35*	0·46 *8·72*	0·860	0·506
1·00 *10·05*	5	0·89 *12·42*	0·51 *25·10*	0·890	0·512
1·05 *16·29*	5	0·93 *5·92*	0·55 *10·58*	0·885	0·526

to decide whether this occurs in this instance, or whether there is merely a gradual fall in the value of k near the upper limit of the size range, as frequently occurs.   Reference to table II will show that the values of C (coefficient of variation) for the mean antennal and elytral lengths in this largest size group (elytra length 1·02–1·08 mm.) are smaller than the values for the two smallest size groups.   This means that the variation in the elytral and antennal lengths in this largest size group is less than in the two smallest groups, the means of which fall on a straight line; so that the fact that the means of this largest size group do not fall on the line is unlikely to be due to chance, and may be assumed to indicate a true decrease in the value of k.

TABLE IV.

Grouped data.   Measurements in millimetres.   The figures in *italics* are the values of C, the coefficient of variability.

E. Mean elytra lengths	No. of specimens per group	T. Mean thorax widths	T/E
	27 male *turcicus*.		
0·91 *5·75*	7	0·45 *9·12*	0·494
1·01 *13·47*	8	0·48 *14·68*	0·476
1·14 *2·85*	9	0·58 *14·38*	0·505
1·22 *1·56*	3	0·62 *2·72*	0·507
	36 male *minutus*.		
0·79 *13·22*	3	0·42 *6·98*	0·535
0·86 *10·58*	7	0·46 *23·60*	0·535
0·92 *4·07*	10	0·52 *24·40*	0·565
0·97 *9·55*	8	0·56 *11·43*	0·580
1·04 *5·78*	8	0·61 *12·00*	0·580

In the males of *minutus*, unlike those of *turcicus*, the antennae do display a growth gradient.   It will be seen from table V, which summarises the values

TABLE V.

Values of k, the coefficient of differential growth ratio.

Species of *Laemophloeus*		Length of elytra = standard dimension				Length of antenna less last 3 segments = standard dimension
		Antennae			Thorax width	
		Whole	Last 3 segments	Re-mainder		Last 3 segments of antennae
turcicus	♂♂	1·92	1·88	1·88	1·07	1·00
	♀♀	1·03	—	—	0·81	—
minutus	♂♂	2·25	2·60	2·00	1·33	1·23
	♀♀	1·23	—	—	1·13	—
ferrugineus	♂♂	1·30	—	—	1·19	—

of k, that the last three segments of the antennae in male *minutus* display positive differential growth with respect to the remainder ($k = 1\cdot23$). When the values of the two parts of the antennae are plotted against those of the elytra, the values of k are 2·60 for the last three segments and 2·00 for the remainder, and the mean of these two values, 2·30, is very close to that for the whole antennae (2·25), as it ought to be.

The width of the thorax (see table IV) also displays positive differential growth with respect to the length of the elytra ($k = 1\cdot33$).

Females. In the females of *minutus* (table III) there is positive differential growth of the antennae ($k = 1\cdot23$) and of the width of the thorax ($k = 1\cdot13$).

Differential growth in L. ferrugineus Stephens.

In a series of 20 male *ferrugineus* the length of the antennae and elytra and the width of the thorax were measured (table III). A small degree of positive differential growth of the antennae ($k = 1\cdot30$) and width of the thorax ($k = 1\cdot19$) was found.

DISCUSSION.

In addition to the considerable interspecific and intersexual differences in the values of k (see table V), there are other metrical differences which are shown by the various tables. For example, it will be seen from table II that the antennae of male *minutus* are longer than those of male *turcicus* of equal elytra length (size); for instance, *L. turcicus* with a mean elytra length of 1·02 mm. have a mean antennal length of 1·27 mm., while *minutus* with a mean elytra length of 1·04 mm. have a mean antennal length of 1·56 mm., but the ranges in length of the antennae overlap broadly. The same is true of the width of the thorax (table IV). If the values of the ratio antennal length divided by elytral length (A/E) in the males of *minutus* and *turcicus* are examined (table II, A/E), it will be seen that the range of values of this ratio also overlap broadly, but the values of the ratio thorax width/elytral length (T/E) do not (table IV), for the thorax of *minutus* is always relatively wider than that of *turcicus*.

Much the same is true of the females of these species. The length of the antennae is about the same in specimens of equal size (table III), but the width of the thorax is greater in *minutus* than in *turcicus* of equal size. The values of the ratio A/E overlap, but those of T/E do not, the values being higher in *minutus*.

The various differences recorded here in the values of k, and in the absolute and relative sizes of certain parts of the body, are probably quite as much characters of the species as the purely qualitative ones, such as the nature of the punctures. The presence of the latter type of character makes it unnecessary, for purposes of identification, to employ the former; though it might be less troublesome to determine the ratio thorax width/elytra length than to examine the genitalia. One might give the following as a supplement to the key on p. 29.

Ratio thorax width/elytra length.

				L. turcicus	L. minutus
♂♂	.	.	.	0·49–0·51	0·53–0·58
♀♀	.	.	.	0·46–0·45	0·50–0·53

Although the ratio thorax width/elytra length is probably not of much practical importance in distinguishing between *O. minutus* and *turcicus*, it is interesting to note that Johnson (1939) found that the ratio head width/length of 3rd antennal segment was the most reliable character for distinguishing between *Cimex lectularius* L., the bed bug, and *C. columbarius* Jenyns, the pigeon bug. Johnson found that the ratio length of 3rd/length of 4th antennal segment, which was formerly used for distinguishing these insects, was of very little use because the range of values of the ratios overlap completely. For the same reason the ratio antennal length/body length is of no use for distinguishing between the males of *L. minutus* and *turcicus* (see table I). Johnson also found that the values of the ratio length of 3rd/length of 4th antennal segment increased during the growth of the insect; that is to say, the growth rate of the 3rd segment was greater than that of the 4th, and there was therefore relative growth between these two segments.
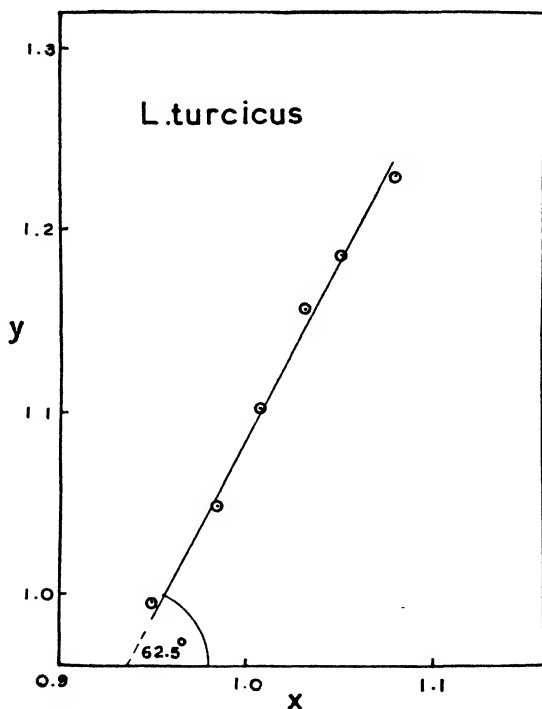
Fig. 1.—*L. turcicus* Grouvelle. Males. Graph of the logarithms of the mean elytra lengths, *x*, plotted against the logarithms of the mean antennal lengths, *y*. To avoid minus quantities the values of the means have been multiplied by 10.

Table III shows that in the males of *ferrugineus* the ratio length of antenna/length of elytra varies between 0·85 and 0·89, values which are much the same as those of the females of *minutus* and *turcicus*. In the males of the last two species the value of the ratio is always more than unity, as the antennae are always longer than the elytra. Richards (1938) has suggested that if metrical characters of this sort were determined for most of the members of a group, it might be found that the values always lay between certain limits; these

values might then be used to determine whether or not particular forms belonged to the group. In the present instance the possession by the male of antennae shorter or longer than the elytra might be a character of this sort; *L. ferrugineus* and the species near to *ater* belonging to one group, and *L. minutus* and *turcicus* to the other.
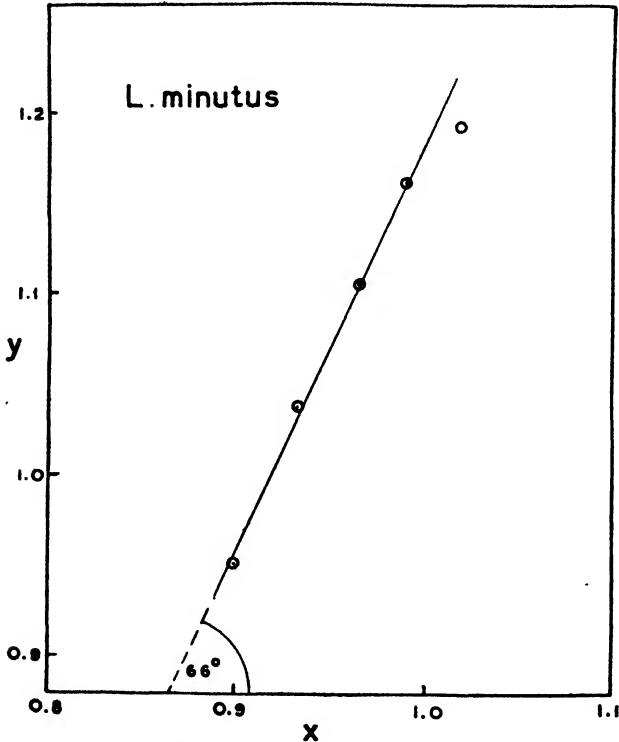

Fig. 2.—*L. minutus* Olivier. Males. Graph of the logarithms of the mean elytra lengths, *x*, plotted against the logarithms of the mean antennal lengths, *y*. To avoid minus quantities the values of the means have been multiplied by 10.

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THE SPECIES OF *LAEMOPHLOEUS* (COLEOPTERA : CUCUJIDAE) OCCURRING IN STORED FOODS IN THE BRITISH ISLES

By J. A. REID, B.Sc., A.R.C.S., F.R.E.S.

Two or three species of small beetles of the genus *Laemophloeus* are frequently found in stored products, such as grain, cacao, spices, etc., in the British Isles. Identification was found difficult, and the object of the present study was to discover satisfactory characters for the separation of these species.
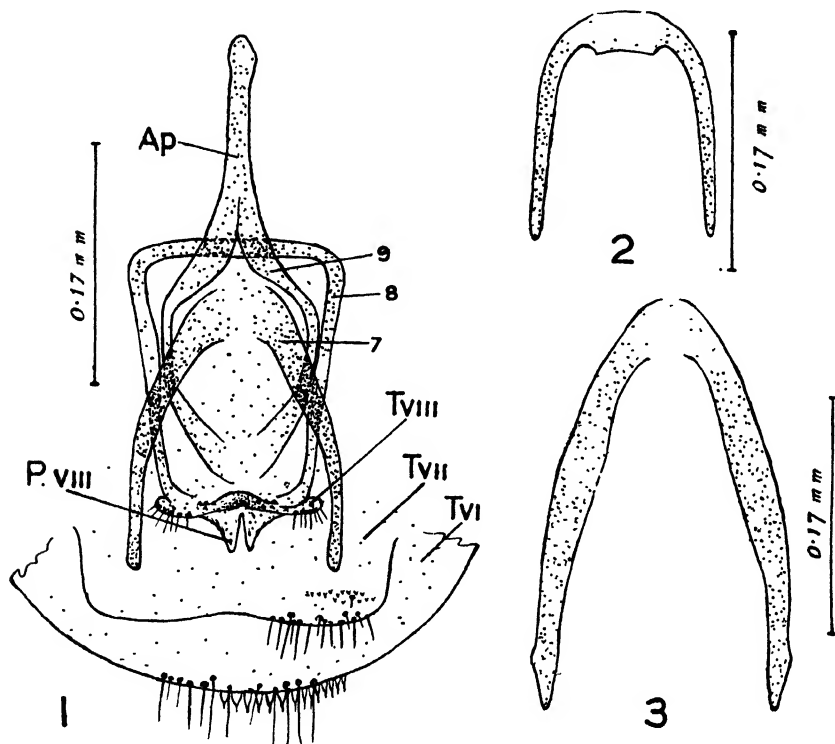
FIGS. 1–3.—1, *L. turcicus* Grouvelle male; sclerotisations associated with abdominal segments VII–IX; 7, 8, 9, sclerotisations of respective segments, Ap, apodeme on sclerotisation of IX, P VIII, process of tergite VIII, T VI–VIII, tergites. 2, *L. minutus* Olivier male; sclerotisation of segment VII. 3, *L. ferrugineus* Stephens male; the same.

The work was done at the Field Station of the Imperial College of Science and Technology, under the direction of Professor J. W. Munro, to whom I wish to express my thanks. I thank also Dr. K. G. Blair of the British Museum (Natural History) for kind assistance.

The difficulty was to distinguish between *Laemophloeus ferrugineus* Stephens, *L. minutus* Olivier (*pusillus* Schönherr), and *L. turcicus* Grouvelle, and little

progress was made until the genitalia were examined. The genitalia and associated structures were found to provide a sure means of separating either sex of these three species; after this discovery external differences were found which are incorporated in the key.

When the species were separated, it was noticed that the length of the antennae in the males of *L. minutus* and *L. turcicus* varied between very wide limits. Dr. O. W. Richards, to whom I am much indebted for valuable advice, suggested that these organs might display heterogonic growth of the type investigated by J. S. Huxley (1932).   The essence of this type of variation is that the organ concerned, instead of forming a constant proportion of the total bulk of the animal, is relatively larger with respect to the rest of the body, in large specimens than in small.
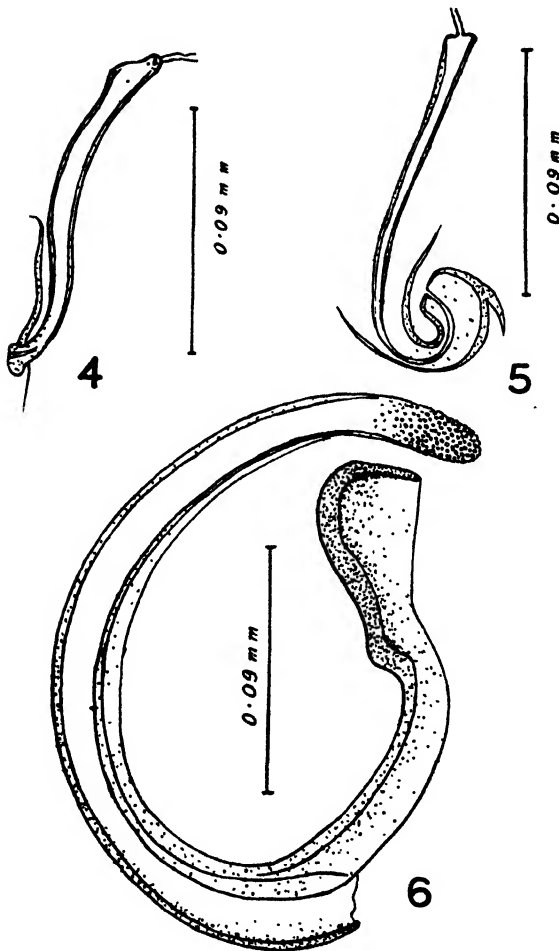
FIGS. 4–6.—4, *L. turcicus*, female; sclerotised portions of spermatheca.   5, *L. minutus*, female; the same.   6, *L. ferrugineus*, female; the same.

A series of measurements was made, and analysis of the figures (data to be published elsewhere) showed that the antennae of the males in *L. minutus* and *L. turcicus* did in fact exhibit heterogony. The great variability in the length of the antennae was one of the main causes of the difficulty experienced in identification. If the key given by Richards and Herford (1930 : 370) is used and reliance is placed mainly on the antennal characters, large males of both *turcicus* and *minutus* would probably be identified as *turcicus*, and small males of both species as *minutus*.

I. A key to the species of *Laemophloeus* recorded from stored products in the British Isles.

1. Hind angles of the thorax blunt. Species somewhat resembling *ferrugineus* but thorax more slender   .   .   .   .   . Species indet., near *ater* Erichson.
–. Hind angles of the thorax sharp pointed.   .   .   .   .   2.
2. Scutellum triangular. Thorax more shining with strong side keels, and the hind angles produced into fine points. Elytra relatively smooth and shining   .   .   .   . *janeti* Grouvelle.
–. Scutellum strongly transverse. Thorax less shining, the side keels less developed and the hind angles less sharply produced. Elytra duller .   . 3.
3. Thorax strongly to moderately contracted behind. Antennae not more than half the body-length, the terminal segment not more than twice as long as broad, almost parallel-sided (fig. 10). Head and thorax finely and usually sparsely punctured. Males with a blunt tooth on the ventral side of each mandible near the base   .   .   .   . *ferrugineus* Stephens.
–. Thorax only slightly contracted behind. Antennae from a half to more than three-quarters the body-length; length of terminal segment varying accordingly, if only about twice as long as broad (♀♀), not parallel-sided but widening distally (fig. 11). Head and thorax nearly always more strongly and closely punctured. Males without a tooth on the ventral side of the mandibles near the base.   .   .   .   . 4.
4. Thorax distinctly transverse, without a small median longitudinal impunctate area, the punctures small to moderate sized. Front angles of the thorax slightly more rounded, hind angles slightly less acute. Eyes less convex. Terminal segment of the antennae in the males a little less expanded distally (fig. 13) .   .   .   . *minutus* Olivier.
–. Thorax not distinctly transverse, often with a small median longitudinal impunctate area, the punctures usually large and shallow. Front angles of the thorax less rounded, hind angles more acute. Eyes more convex. Terminal segment of the antennae in the males a little more expanded distally (fig. 12) .   .   .   . *turcicus* Grouvelle.

Specimens of all the species except *L. janeti* have been compared with material in the British Museum.

Joy (1932) gives the following key for separating *L. turcicus* and *minutus* :—

Eyes less convex; thorax less strongly punctured; joint 3 of antennae shorter than 2 and 4 .   .   .   . *minutus*.
Eyes more convex; thorax more strongly punctured; joint 3 of antennae as long as 2 and 4 .   .   .   . *turcicus*.

The difference in the convexity of the eyes appears to be a sound character and has been included in the key, but the antennal character does not seem to me to hold good.
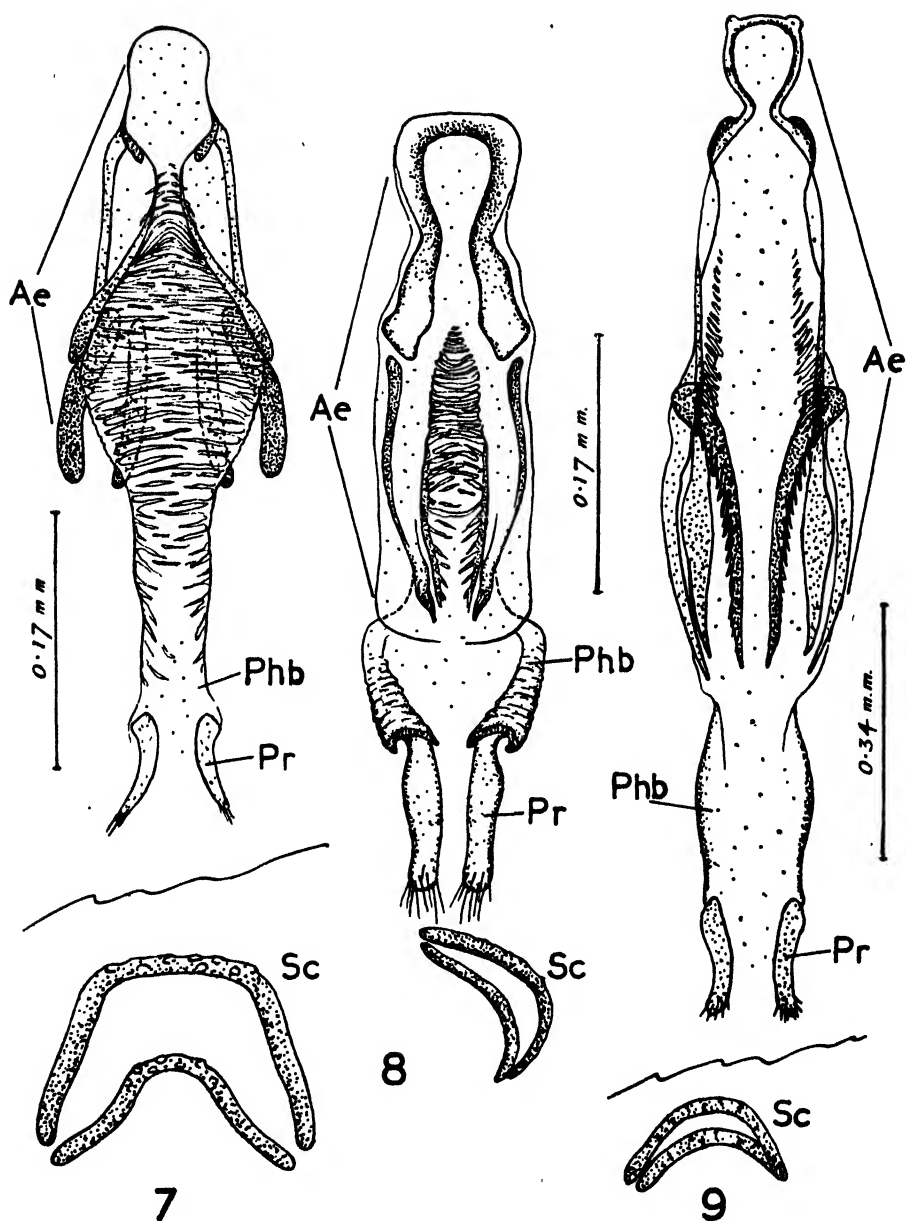
FIGS. 7–9.—7, *L. turcicus*; sclerotised parts of male genitalia, ventral view; Ae, aedeagus, Phb, phallobase, Pr, parameres, Sc, sclerotisations, possibly in the walls of the genital chamber. 8, *L. minutus*; the same. 9, *L. ferrugineus*; the same.

The key I have given includes the four species recorded by Richards and Herford (1930), plus a fifth (species near to *ater*) discovered during the course of the work, among the material of *ferrugineus* in the collection at the Field Station. There were 3 females and 1 male of this species, taken in wheat refuse in a mill at Sonning, Berks, October 1929. Using Reitter's key (*Fauna Germanica, Käfer*) this species runs down to *ater* Erichson, but comparison shows that it is not the same as the species recognised in this country as *ater*, although related to it. The group of species to which it evidently belongs, in company with *ater* and *ferrugineus*, is characterised by the short antennae in both sexes, the presence of a tooth on the underside of the mandibles near the base in the males, and the marked contraction of the thorax behind, especially in the males. The species in question is more slender than *ferrugineus*, while the mandibles and labrum, especially in the male, are relatively larger, and the antennae a little shorter; the colour is more or less ferruginous.

Richards and Herford record *L. ferrugineus* and *L. minutus* as cosmopolitan; they are certainly the commonest species in stored products in Britain. *L. turcicus* was first recorded in this country by Joy (1925) from a flour mill at Twyford near Reading, 18 Sept. 1924, and again (Joy, 1932) from a granary in Reading, 2 Feb. 1932. There are specimens in the collection at the Field Station from a mill at Sonning, Berks, Oct. 1929, and from a mill in Reading, Aug. 1930; evidently this species is established in the Reading district. *L. janeti* is recorded by Richards and Herford from a single adult specimen found in cacao from West Africa, at Wapping, London, 4 May 1928.

II. The genitalia and associated structures.

It may be appreciated from examination of the key that the external differences, especially between *L. minutus* and *turcicus*, are small and variable, but, as figs. 1 to 9 show, it is quite otherwise with the genitalia. In order to examine these structures the abdomen was dissected off and treated with potash, washed in acetic acid and then placed on a slide in a drop of de Faure's fluid. The tergites were separated from the sternites with fine needles and the genitalia came away with the tergites and could then be examined under the microscope. Only the genitalia of *L. ferrugineus, minutus* and *turcicus* have been examined.

Fig. 1 is a ventral view of the sclerotisations associated with segments VII to IX in the male of *turcicus*; the genitalia are not shown. Except for the sclerotisation of segment VII (figs. 1, 2 and 3), the shape of which is specific, the appearance of these structures in the males of *minutus* and *ferrugineus* is very similar to that of *turcicus*. The females have the usual rod-like sclerotisations in the walls of the last few segments of the abdomen, but these do not show specific differences. The females are readily identified by the shape of the sclerotised portion of the spermatheca (figs. 4, 5 and 6). The sclerotised portions of the male genitalia are depicted in ventral view in figs. 7, 8 and 9; no serious attempt has been made to interpret their structure, but it will be seen that almost every part differs among the three species. The shape of the parameres (Snodgrass, 1935 : 597, = lateral lobes, Sharp and Muir, 1912) differs in the three species, but the larger differences occur in the sclerotisations of the aedeagus.

It is convenient to be able to distinguish the sexes of *L. ferrugineus, turcicus* and *minutus* from external features. Many parts of the body display some degree of difference in the sexes. The tarsal formula of the males is 5. 5. 4., that of the females 5. 5. 5. The antennae of the males, particularly in large specimens of
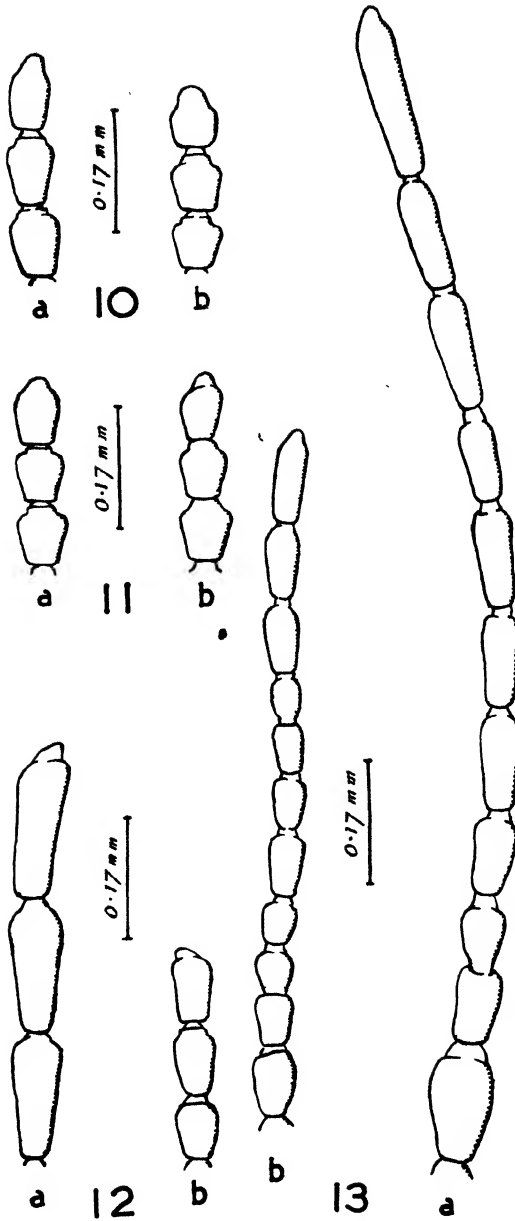
FIGS. 10–13.—10, *L. ferrugineus*; a, male, last three segments of antenna; b, female, the same. 11; a, *L. minutus*, female, last three segments of antenna; b, *L. turcicus*, female, the same. 12, *L. turcicus*, male, last three segments of antenna; a, large specimen; b, small specimen. 13, *L. minutus*, male, whole antenna; a, large specimen; b, small specimen.

minutus and *turcicus*, are longer than those of the females, though not much so in *ferrugineus*. The last three segments of the antennae in the females are always stouter and shorter than those of the males; this difference is very marked between large males of *minutus* and *turcicus* and females of these species. The thorax tends to be more contracted behind and its maximum width relatively greater in the males, especially those of *ferrugineus*; also the head of the males tends to be somewhat larger. There are other small differences, but usually the antennal characters form the easiest means of sexing mounted specimens (figs. 10 to 13).

It may be mentioned here as a point of interest that both sexes of these three species have what appears to be stridulatory apparatus. This consists of two pairs of file areas; each pair is composed of an area on the inside of the elytra near the outer edge towards the base and one that appears to be on the mese-pimeron of the metathorax. The appearance of the apparatus is the same in all three species; the file areas consisting of a large number of minute teeth set close together, and all sloping the same way.

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Book Notice.

The biological campaign against prickly-pear. By A. P. Dodd. 8vo. Brisbane (Commonwealth Prickly Pear Board), 1940. pp. ii + 177, 37 pls., 6 graphs, 1 map.

"This bulletin is intended to be a record of the biological investigations carried out during the campaign " [against the prickly-pear]. This is the statement given in the Introduction to the work. It is known generally that the problem of eradication of the cactus known as Prickly-Pear in Australia was probably the foremost problem confronting the Governments of Queensland and New South Wales from 1920 to 1940. At the height of its spread the cactus had made virtually useless an area of approximately 60,000,000 acres, the reclamation of which by mechanical or chemical methods was out of the question by reason of the expense. The whole of this area has been, or will very shortly be, so cleared of the weed that it may be utilised for agricultural purposes.

This book is the story of that achievement. It is a full historical summary of the origin, study and results obtained by the Commonwealth Prickly Pear Board which was set up in 1920 and terminated in 1939. The success of the control is of course due to the moth *Cactoblastis cactorum*, a native of the Argentine, a gregarious feeder which tunnels in the segments and stems of the prickly-pear and reduces the plants to a rotting mass.

A special welcome may be accorded to this most interesting record of a very spectacular success in the control of a first-rate plant-pest by an insect. It is worthy of a very wide distribution.

THE PREY OF A POPULATION OF *MACHIMUS ATRICAPILLUS* FALLEN (DIPTERA)

By L. Parmenter, F.R.E.S.

THOUGH Dr. B. M. Hobby (1931, *Trans. ent. Soc. S. Eng.* **6** : 1–42) was able to collect 91 records of *Machimus atricapillus* Fallen with prey, no previous attempt has been made to study a population of the species in one locality. Therefore, when in Cornwall in August, 1941, I found the species to be common in a stretch of about 400 yards of a hedge bordering a wood at Lelant, I collected as many specimens with prey as I could.

The fly was rarely seen except on sunny days. It was found on branches and trunks of trees, telegraph poles and sunny leaves of plants from 1 to 10 feet off the ground. The favourite attitude taken up by the fly was to lie on one side with legs outstretched. Whether this was to enable the sun to shine along the whole length of the body or to keep better watch 1 could not tell. Sunny patches were preferred for resting and invariably the prey was brought to a sunny spot. The Asilid would alight on a telegraph pole on which were massed a hundred or so *Musca corvina*, 50 *Pollenia rudis* and perhaps three or four of its own species. Though several hours were devoted to the watching of the species I did not once see an attempt to capture a resting fly. All captures were flying insects, sometimes made by means of a " capture dart " but occasionally when just about to alight after a patrol. At these times I imagine the *Machimus* would suddenly catch sight of a fly alighting and drop upon it. Though movement brought death to the victim, speedy and erratic flight brought safety. The commonest insects flying at the time were *Musca corvina*, *Pollenia rudis* and *Eumerus tuberculatus* Rondani. *Eumerus* has a speedy erratic flight as it seeks its host plants. *Musca*, though fast, is steadier in flight, and *Pollenia* is fairly slow. No *Eumerus* was seen to be captured, but *Pollenia* was a frequent victim. Other slow flyers captured included *Syrphus balteatus*, *Melanostoma scalare* and *Beris vallata*. Capture darts and flying attacks were made at pieces of passing, falling leaves and at large wasps, but on close approach the Asilid would not press home its attack.

The specimens are too few to indicate any sexual preference. As to colour of prey, both dull and brightly-hued insects were taken.

The prey appeared to be killed instantly. Several times I had a pill-box over captor and prey almost as they alighted and the Asilid generally dropped as if dead. Though the victim would also slide inert over the floor of the box, the Asilid alone recovered. This feigning of death was not a regular habit although it occurred several times.

I saw no sign of actual or attempted cannibalism, though this is known to occur in several species of ASILIDAE and other predatory flies. At times a *Machimus* would alight on another's back, but this always proved to be a case of coupling. They would first be head to head but soon one would turn until they sat tail to tail and if disturbed would fly off in this attitude. Pairing lasted several minutes and probably many, as I saw no uncoupling except of a disturbed pair in which coupling had lasted 5 minutes 20 seconds. No form of courtship display was seen.

Table of Prey of 24 ♂, 17 ♀ *Machimus atricapillus* Fallen.

Captor sex	Diptera	
	STRATIOMYIDAE	
♂	*Beris vallata* Forster ♀	5 Aug. 1941
♀	*Chorisops tibialis* Meigen ♀	do.
	DOLICHOPODIDAE	
♀	*Xanthochlorus tenellus* Wiedemann ♀	do.
♂	*Chrysotus gramineus* Fallen ♀	7 Aug. 1941
	EMPIDIDAE	
♀	Empid sp. ♂	2 Aug. 1941
	PIPUNCULIDAE	
♂	*Pipunculus* sp. ♂	do.
♂	*Pipunculus* sp. ♂	do.
	SYRPHIDIDAE	
♀	*Melanostoma scalare* Fabricius ♂	2 Aug. 1941
♀	*Melanostoma scalare* Fabricius ♀	do.
♂	*Melanostoma scalare* Fabricius ♂	do.
♀	*Melanostoma scalare* Fabricius ♂	5 Aug. 1941
♀	*Melanostoma scalare* Fabricius ♂	do.
♂	*Syrphus balteatus* Degeer ♂	do.
♀	*Syrphus balteatus* Degeer ♂	7 Aug. 1941
♀	*Syrphus balteatus* Degeer ♂	do.
Also	*Syrphus balteatus* Degeer seen, not taken	5 Aug. 1941
	MUSCIDAE	
♂	*Musca corvina* Fabricius ♂	2 Aug. 1941
♂	*Musca corvina* Fabricius ♂	5 Aug. 1941
♀	*Musca corvina* Fabricius ♀	do.
♂	Anthomyid sp. ♀	do.
♀	Anthomyid sp. ♂	do.
	TACHINIDAE	
♂	Tachinid sp. ♀	do.
5 ♂, 3 ♀	*Pollenia rudis* Fabricius *s.l.* 5 ♂, 3 ♀	do.
2 ♂	*Pollenia rudis* Fabricius *s.l.* 2 ♂	7 Aug. 1941
Also 2	*Pollenia rudis* Fabricius *s.l.* seen, not taken	5 Aug. 1941
	Coleoptera	
♂	Coleopteron	2 Aug. 1941
	Hemiptera	
♀	Hemipteron-froghopper	do.
3 ♂, 1 ♀	small Hemiptera	5 Aug. 1941
♂	small Hemiptera	7 Aug. 1941
Also 2	small Hemiptera seen, not taken	5 Aug. 1941
	ICHNEUMONIDAE	
1 ♂, 1 ♀	Ichneumonid sp.	5 Aug. 1941
♂	Ichneumonid sp.	7 Aug. 1941

The material will be preserved in the Hope Department, University Museum, Oxford.

A NOTE ON THE PREDATORY LARVA OF THE MOSQUITO CULEX (LUTZIA) TIGRIPES GRANDPRÉ & CHARMOY (DIPTERA)

By A. J. HADDOW, M.B., F.R.E.S.

(*Medical Research Council, Junior Fellow in Tropical Medicine.*)

THE observations recorded in this note were made at Kisumu, Nyanza Province, Kenya Colony.

During the early months of 1940 heavy rainfall at Kisumu was accompanied by a very marked increase in the numbers of *Anopheles gambiae* Giles, the principal malaria carrier of the area. At this time many borrow-pits at first swarming with *A. gambiae* larvae were noticed, at a later date, to be inhabited exclusively by larvae of *Culex* (*Lutzia*) *tigripes*. It is known that this larva is predatory on other mosquito larvae but the extent of its usefulness has not been determined. As it appeared almost certain that the borrow-pits had been denuded of their large *A. gambiae* population by the *Lutzia* larvae, a few simple experiments were carried out to find how many larvae could be eaten in a short period.

EXPERIMENT 1.

10 *Lutzia* larvae were isolated in small bowls. To each bowl 10 second-stage *A. gambiae* larvae were added and the bowls were left for 15 hours overnight. Next morning it was found that :—

In 8 bowls all 10 *A. gambiae* larvae had been eaten.
In each of the other 2 bowls, 9 *A. gambiae* larvae had been eaten.

The mean number consumed was thus more than 9.

EXPERIMENT 2.

10 *Lutzia* larvae were isolated as above. To each bowl 10 fourth-stage *A. gambiae* larvae were added. The bowls were left for 15 hours overnight. The results were :—

In 1 bowl 1 *A. gambiae* larva had been eaten.
In 1 bowl 2 *A. gambiae* larvae had been eaten.
In each of 6 bowls 5 *A. gambiae* larvae had been eaten.
In each of 2 bowls 7 *A. gambiae* larvae had been eaten.

The mean number consumed was thus almost 5.

EXPERIMENT 3.

10 *Lutzia* larvae were isolated as above. To each bowl 10 *A. gambiae* pupae were added and the bowls were left for 15 hours overnight. The results were :—

In each of 4 bowls no pupae had been eaten.
In each of 2 bowls 1 *A. gambiae* pupa had been eaten.
In each of 3 bowls 2 *A. gambiae* pupae had been eaten.
In 1 bowl 5 *A. gambiae* pupae had been eaten.

The mean number consumed was thus just over 1. Only the tails were consumed, probably on account of the fairly dense chitinisation of the cephalothorax.

Direct observations were made on the method of feeding. It was found that *L. tigripes* larvae almost always seize large or small Anopheline or Culicine larvae by the tail. In the case of a large larva, the *Lutzia* is dragged about the jar by the galvanically jerking victim. The specialised mouth-brushes,

however, appear to penetrate the soft abdominal integument almost immediately and the prey rarely escapes from this firm grip. Effective struggles are of very short duration, seldom lasting more than a minute, though slow movements often continue after feeding has begun, sometimes till almost the entire abdomen has been consumed. The time required for complete consumption of a large larva varies from 15 to 30 minutes. The abdomen is eaten first and disappears very quickly. The head and thorax are consumed more slowly and are often discarded.

In the case of pupae, the small number eaten is not due to unwillingness to accept food of this type, but to the more highly chitinised integument of the pupa and to its very powerful swimming movements, which usually enable it to break loose. Very often this occurs when the *Lutzia* attempts to shift its grip from the tail-paddles, where the pupa is usually seized first, to a spot farther up the abdomen. During 30 minutes observation of a jar, 20 pupae were seized but only 1 was effectively held and eaten. In the other instances the pupa, though sometimes held for almost a minute, finally escaped without apparent injury.

Hopkins (1936) states that *Lutzia* larvae eat one another with reluctance, in the absence of other food. The present observations do not confirm this statement. Larvae placed in a large jar, with abundant *A. gambiae* as food, attacked one another repeatedly but, as in the case of pupal food, the seized larva was rarely damaged as it usually managed to break away in a few seconds with swimming movements of great rapidity and violence. There was no question of the predator relinquishing its prey voluntarily. Large *Lutzia* larvae are able to hold small larvae of their own species and devour them quite indiscriminately in the presence of abundant Anopheline food.

Hopkins (*loc. cit.*) also states that larvae are seized only when they have come into contact with the mouth-brushes of the predator. Certainly this occurs frequently, and the *Lutzia* lies in wait at the surface and does not hunt its prey. More often, however, the food-larva is captured by a very rapid darting movement, rather reminiscent of a snake striking. This occurs whenever a larva comes within striking-distance and the *Lutzia* will even bend its body round to seize a larva approaching from almost directly behind. The judgment is very accurate and though the food-larva may ultimately escape, it is almost always caught and held at first.

At Kisumu the main breeding-place was found to be muddy pools and borrow-pits frequented by *A. gambiae*, though larvae were sometimes taken in reedy pools and swamps, breeding-places of *A. funestus*, *A. coustani* and *A. pharoensis*. Hopkins (*loc. cit.*) mentions that tree-holes are rare breeding-places for this species. It is interesting to record that a large tree-hole, recently searched at Entebbe, yielded several larvae of *L. tigripes*, together with 2 larvae of *Megarhinus brevipalpis* Theobald v. *conradti* Grunberg, and very numerous larvae of *Aëdes (Stegomyia) apicoargenteus* Theobald, *A. (S.) africanus* Theobald and *Culex (Culiciomyia) nebulosus* Theobald.

The eggs are laid in large rafts. During work at Kisumu some small pits were dug during the rains to provide an easily accessible supply of *A. gambiae* larvae. On the day after the pits had been dug, *Lutzia* egg-rafts were present, though no *A. gambiae* eggs were laid till the second day. *A. gambiae* failed to establish itself in these pools, as all the young larvae were eaten by the *Lutzia*, which hatched first.

REFERENCE.

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NOTES BY E. BURTT, B.SC., F.R.E.S., ON A SPECIES OF *PALOPHUS* (PROBABLY *EPISCOPALIS* KIRBY): A GIANT PHASMID (ORTHO- PTERA) FROM TANGANYIKA TERRITORY

By Professor G. D. Hale CARPENTER, M.B.E., D.M., F.R.E.S.

MR. ERIC BURTT, entomologist at Tinde Laboratory, near Lohumbo, Tan- ganyika Territory, wrote to me in July 1941 that he had seen in 1940 a male of this huge insect which measured fifteen and a half inches from the tips of the front legs to the tips of the hind legs : two females were seen, but no measure- ments sent. In 1941 he met with three females only. One of the first females, enclosed in a cage, deposited upon the gauze numbers of ova which, as Mr. Burtt pointed out, have a curious resemblance in shape to a Lycaenid pupa : they measure about eight mm. long and three across and are dark grey-brown in colour.

I asked Mr. Burtt to send an adult insect which could be identified, and he kindly did so, writing the accompanying notes on 19th January 1942. " The Phasmid eggs, the largest insect eggs I have encountered, are beautifully procryptically coloured, but I do not know any seeds of similar form. I suggest it is probable that they do not represent seeds (as do eggs of other Phasmids) but nodes or warty excrescences on twigs. The female always glues these eggs ; she does not drop them about loose at all.

" The specimen I am sending you is rather a magnificent brute, is it not ? The procrypsis is marvellous owing to the subdivision of the lower wings into two areas, of which the grey, bark-like anterior portion covers the black posterior portion. The upper wings are greatly reduced to form scale-like objects.

" The gaudy black lower wings are used by the insect to give warning. It rests, of course, with its wings folded and only the grey, bark-like, part showing. When disturbed it swishes its wings open in the position shown in the set speci- men : the opening of the wings is accompanied by quite a loud hissing, swishing, noise. The wings are beaten up and down about once per second, say ten or a dozen times, and then held open while the insect moves away. As soon as a calmer atmosphere is restored the wings are shut again ; *i.e.* after a few seconds of display."

The specimen, which was exhibited, was kindly examined by Dr. B. P. Uvarov, who identified it as *Palophus episcopalis* Kirby ?, from literature avail- able, the collections not being at present accessible. It shows regeneration of the right front leg, which is considerably shorter and smaller, all parts being reduced. An ovum had been deposited on the left femur from which a larva had hatched. Unfortunately this had been sent pinned and had been so damaged by the process that it could not be properly displayed. The total length of the com- plete and very fine specimen, which had travelled safely because of very careful packing, is just over fourteen inches.

The combination of extreme procrypsis with a " terrifying " procedure when the insect is disturbed is extremely interesting. It is, of course, well known among MANTIDAE.

The sudden display of a large, rustling, black area would certainly be as disconcerting to an inexperienced enemy as was the display of the Mantid *Idolum diabolicum* to the young monkey with which I experimented (see 1921,

Trans. ent. Soc. Lond. **1921** : 52).   Dr. Julian Huxley, F.R.S., in his comprehensive study of the biological functions of colour (1938, *Proc. VIII int. ornith. Congr. Oxford* 1934 : 430–455) would classify this behaviour of the Phasmid as "Pseud-antaposematic," *i.e.* bluff and terrifying threat behaviour.   There is no reason at all, either *a priori* or *ex experimento*, for supposing the highly procryptic Phasmids to be anything but highly edible.   In the case of *Idolum diabolicum* my monkey found on further experience of other specimens that they could be overcome and were very good to eat.

RESEMBLANCE BETWEEN AN AGARISTID AND A XYLORYCTID (LEP. HETEROCERA)

By Professor G. D. Hale CARPENTER.

CAPTAIN T. H. E. JACKSON, F.R.E.S., of Kitale, Kenya (now serving in the King's African Rifles), recently sent to Oxford some specimens with the note " Herewith a wonderful case of mimicry from Bwamba Valley [the Uganda section of the Semliki valley], August 1941, taken by native collectors at the same place and in the same month, both diurnal.   The model is that common blue and white Uganda Agaristid; the mimic, a ' micro.' "

Several specimens of each were received.   Dr. Karl Jordan, F.R.S., kindly identified the Agaristid as *Massaga maritona* Butler 1868, described from Sierra Leone, where the white band is slightly narrower than in the Uganda specimens. Mr. H. Stringer at the British Museum (Natural History) kindly identified the presumed mimic as the Tineine Xyloryctid *Cyanocrates grandis* (Druce) 1912, described with an excellent coloured figure in 1912, *Ent. mon. Mag.* **48** : 133, Pl. X, fig. 9 (as *Onmatothelxis*).

The Agaristid has the base of the hind-wings of the same intense blue as the base of the fore-wing, but except for this the simple pattern of white bar crossing deep-blue wings is the same in the two species.

Both have a certain amount of red, shown on the head and thorax of the Agaristid, but on the long femora and tibiae of the hind legs of the Xyloryctid: it would be of the greatest interest to know how this colour is displayed in flight.   I have been unable to discover that this likeness has been noticed before, but it may reasonably be claimed as a possible case of mimicry, for the day-flying AGARISTIDAE have many of the characters of relatively distasteful insects.   The XYLORYCTIDAE are unusually large for Tineina : one of the two females sent measures 60 millimetres across the two fore-wings, the male is smaller, measuring between 45 and 50 mm.   No females of *Massaga* were sent : the males are of about the same size as the *Cyanocrates*.

ENTOMOLOGICAL GEMS

By L. G. Hulls, F.R.E.S.

Although the origin of the art of engraving upon hard and precious stones is lost in antiquity, specimens of such work abound in museums and art institutions throughout the world. They are, speaking generally, of interest only to artists, scholars, and members of the fraternity which rejoice in the appellation "expert." It is difficult to believe that these ancient stone engravings can offer anything of interest to the entomologist, and yet, if one searches diligently enough, quite an appreciable amount of entomological matter is revealed. The writer of these notes, prevented by war conditions from indulging in more ordinary forms of entomology, has, during some long hours of night duty, amused himself by searching for such matter amongst the records of ancient engraved gemstones. The search has been confined to books and other material existing in his own house, and, therefore, it is not to be expected that the notes form a comprehensive study.

The ancient engravers used a variety of mineral substances upon which to exercise their art. They were mostly hard stones, and, although some of them could justly be called "precious stones," it is best to consider them all under the heading of "gemstones." There is a considerable number of them, including such substances as Chalcedony, Emerald, Agate, Beryl, Turquoise, Onyx, Lapis lazuli, Cornelian, Rock Crystal, Jasper, and Sardonyx. From time to time, collections of these engraved gemstones have been formed, mostly by private individuals, and many of them have been copied in the various soft glasses known as pastes. These copies, often extremely good likenesses of the originals, have been the source of much chicanery throughout the centuries. Records of many of these engravings have been made in the form of sulphur impressions, usually coloured red. Towards the end of the 18th century, Baron Philip Stosch travelled about Europe in search of engraved stones, and, from these, he made some 2500 sulphur impressions which have come to be known as "Stosch Sulphurs."

The best known and largest collection of paste and sulphur impressions ever made was that of James Tassie, a native of Glasgow. He managed to gain access to nearly all the most celebrated gem cabinets of Europe, as the result of which he produced a vast collection of paste and sulphur impressions. It must not be thought that Tassie was merely an expert in the production of such impressions. He was, in fact, a fine artist, and executed a large number of portraits of contemporary celebrities. He first modelled the sitter's portrait in wax, and, from these wax models, he made impressions in a hard white enamel of his own invention. These Tassie enamels are much sought after by collectors and are of considerable value.

In 1791, eight years before the death of Tassie, one, R. E. Raspe (said to be the author of the travels of Baron Münchhausen), published in two large volumes a descriptive catalogue of the Tassie collection, which, at the time, consisted of nearly 16,000 pieces. It must have been a colossal labour, and could only have been carried out by a person of considerable learning. The text is given in both English and French, and the introduction is a lengthy dissertation on the art of gem engraving. The title-page reads :—

> "A Descriptive Catalogue of a general collection of Ancient and Modern
> Engraved Gems, Cameos as well as Intaglios, taken from the most

celebrated cabinets in Europe; and cast in coloured pastes, white enamel, and sulphur, by James Tassie, modeller. Arranged and described by R. E. Raspe." 1791.

In these volumes, Raspe has arranged the collection in an orderly and systematic manner, commencing with the hieroglyphics of ancient Egypt and ending with comparatively modern engravings of religious subjects, portraits of sovereigns and other celebrities, and so on. A vast field of ancient history and mythology is covered by this description of a collection which, according to Raspe, " Serves for all the purposes of artists, antiquaries, scholars, men of taste, and even philosophers."

The insects mentioned in the catalogue number eight, which is just two fewer than the number referred to in the Bible. It is of interest to compare the two lists.

Raspe.	*The Bible.*
	Gnat
Bee	Bee
Ant	Ant
Fly	Fly
Grasshopper	Hornet
Locust	Locust
Beetle	Flea
Butterfly	Moth
Louse	Louse
	Coccus (crimson worm)

The louse is only mentioned in connection with one engraving, number 13,347. It has the inscription : " A louse, the worthy ornament and remembrances of the Cynicks and Capuchin Friars." There are but two engravings of bees, and Raspe gives no information concerning them. The locust is mentioned in the heading to a group of engravings, but when the items of the group are referred to individually, the insects are all called grasshoppers. This will be referred to later on when the subject of grasshoppers is dealt with.

The insect which can lay claim to the largest influence over these many designs, is, as might be expected, the scarab beetle. Not only do many of the old Egyptian gemstones carry figures of scarabs, but a large number of the engravings are worked on the flat under-surface of stones which have been fashioned in the shape of scarabs. Egypt cannot be held responsible for the large number of mineral scarabs which are in existence, for it would seem that the scarab fashion (or craze) spread to various other countries. The following notes, extracted from " Maspero's Guide to the Cairo Museum " 1906, are of interest in this connection :—

" . . . The insect of which it is the image is well known. It is the *Ateuchus sacer*, which we so often see near the desert edge, rolling along the ball of dung in which it has deposited its egg, and which, in the cultivated valley, in the evenings, flies to open windows, attracted by the light, and falls heavily into the houses. The Egyptians worshipped it from the most remote antiquity, as they also worshipped other insects, the grasshopper, the cricket, the praying mantis, and the large stag beetles. . . . The scarab readily came to signify all that exists or causes to exist, the organ without which man would not be, namely the heart. . . . So the image of it was multiplied in order to assure to

living and dead alike a continuance of being, and, like all religious emblems held in general esteem, it was used as an ornament in jewellery. . . . The fashion extended to foreign countries; Phoenicia, Cyprus, Greece, Etruria, Carthage, Sardinia, all made scarabs in imitation of Egypt."

In the Tassie Collection the insect next in order of importance is the butterfly, symbol of Psyche. There is a large number of engravings dealing with the amours of Cupid and this lady, in nearly all of which the latter is represented as a butterfly. It would seem that Cupid had a tremendous keenness for the Rhopalocera, for whether he is playing the lyre, fishing, or practising archery, his attention seems always to wander to the butterfly which is sure to be found near by. There are several engravings of Cupid chasing or dallying with a butterfly, the subject being, of course, that disturbing thing Love. There is a charming engraving of Cupid driving a plough drawn by two butterflies, but, unfortunately, the artist has only provided them with two wings apiece. Butterflies occur in engravings dealing with subjects other than the affairs of Cupid and Psyche. Notable amongst these is one of a Peacock (symbol of Juno) being driven by a butterfly which holds reins attached to the bird's neck. Raspe says of this : " A butterfly holding by the bridle the peacock of Juno, which in one of his feet has a branch of palm, and with the other is perched upon a staff, from which a crown hangs. Is this Reason guiding Ambition and Beauty to make them victorious ? "

Flies are prominent in the set of engravings which deal with Jupiter. Apparently, one of the many surnames given to this god was Muscarius, a word signifying to drive away flies. Jupiter, most powerful of all the ancient gods, is better known to most by reason of his association with thunder. It is somewhat surprising to find him portrayed as an elderly gentleman with a beard composed of two fly wings. In one portrait, the head with its beard of fly wings, is so designed as to approximate the shape of a fly at rest. The description of one engraving is : " Head of Jupiter. In the field two flies." Flies occur under other headings in the catalogue, and are referred to again in the next paragraph, which deals mainly with grasshoppers.

Possibly the most interesting of all the stone engravings depicting insects may be found under the heading " Ceres and Plenty." This group is divided into various parts, one of which deals with the attributes of Ceres. It is here that one finds designs incorporating either grasshoppers, locusts, or both. Raspe groups a number of these under the title " Grasshoppers and Locusts," but in his description of the individual items, the insects are all referred to as grasshoppers. Ceres, being the goddess of corn, Raspe very naturally considered that all designs which included spikes of corn in their make-up must allude to her. All engravings containing ploughs were also put into this group. The question arises as to whether or no Raspe's grasshoppers were really locusts. The main title of " Ceres and Plenty " seems to suggest abundant corn crops, and, on this matter, the locusts had a good deal to say. On the other hand, it may be remembered that the ancient Egyptians worshipped the grasshopper. The point is one of interest, and perhaps some expert orthopterist will decide the issue after examining the sulphur impressions.

In one instance, there is an engraving showing a grasshopper (or locust) driving a plough drawn by two flies, and another picture is of a grasshopper on a vine leaf. I have in my possession a sulphur impression which shows a plough, the driver and team of which appear to be moths. There is no reference

to this engraving in the catalogue. Ants appear in this group, and there is one engraving with the title, " A plough with two Ants." There is also one of a car drawn by two ants, one of an ant and a fly, and another of two ants carrying a large grain of barley. One impression, made from an engraved cornelian scarab, has for title, " A Grasshopper upon an ear of corn, with a butterfly upon the wing." In this case the former insect might quite well be meant as a locust, but again, experts must decide.

It is hoped that these brief notes will prove interesting. I have the advantage of possessing not only Raspe's Catalogue, but also many hundreds of the sulphur and paste impressions which once formed part of the famous Tassie Collection.

Handbook of economic entomology for South India. By T. V. Ramakrishna AYYAR. pp. xviii + [ii] + 528, illust. (col.). 8vo. Madras (Superintendent, Government Press), 1940. Price Rs. 4. 12. 0.

This book is the successor to *Some South Indian Insects* by T. Bainbrigge Fletcher, published in 1914 and now out of print. It is by the former Government Entomologist of Madras, and some parts of it have already appeared in Indian Government publications.

It is divided in two parts : General Entomology and Economic Entomology, of which the first comprises 85 pages and the second 450 pages.

The first part of the book is introductory and deals with internal anatomy, physiology, reproduction and classification of insects.

The second part deals with the economic rôle of insects, pest control, the insect pests of crops grown in South India, the pests of the household and of stored products, beneficial insects and a series of appendices on insect pests arranged under the orders of insects, classification, study technique, non-insect pests and insectivorous animals and a bibliography of South Indian economic entomology.

A STUDY OF THE FEEDING OF ADULT STONEFLIES (PLECOPTERA)

By H. B. N. HYNES, Ph.D., A.R.C.S., F.R.E.S.

IN a previous paper (Hynes, 1941) it was shown that, contrary to the general belief, the adults of at least some stoneflies, namely those of the sub-order Filipalpia as opposed to those of the Subulipalpia, feed, the food being the lichens and Protococcales which grow on the trunks and branches of trees. Frison (1935) had previously shown that this occurred in U.S.A., and Newcomer (1918) had shown that in California certain species of *Taeniopteryx* caused damage to fruit trees by eating the buds; European workers had, however, maintained that no species of European stoneflies feed as adults (Schoenemund 1924, Kühtreiber 1934, and Mertens 1923), and supported this contention by stating that the mouth-parts of adult stoneflies are reduced. This latter fact is, however, only true of the Setipalpia; in the Filipalpia the mouth-parts are as fully developed as those of the nymphs.

In view of the general contention that adult stoneflies do not feed, the present investigation was undertaken in order to determine whether or no the feeding of the adults was an important part of the life-history, and although the results obtained are in some respects unsatisfactory they do strongly indicate that access to food is necessary for the survival of at least the species *Nemoura variegata* (Olivier), on which experiments were made.

The species *N. variegata* was chosen for investigation because of its abundance, and also because, being a species which breeds in still water, it is possible to rear collected nymphs to maturity without recourse to the use of running water. This species also has a long emergence period (Hynes, 1940), and experiments can thus be conveniently carried on over a period of weeks. Adults were found to feed satisfactorily on the lichen and Protococcales covering old and dead twigs, and to be able to obtain water from pellets of wet cotton wool. Nymphs were obtained from localities in Surrey and Shropshire during the spring and summer of 1941, and were reared to maturity on a diet of dead oak-leaves in shallow pie-dishes. All adults emerged during the hours of daylight, mostly between 7.30 and 12.30 a.m. G.M.T., and were taken within twelve hours of their emergence and confined at room temperature in pairs, either of the same or of opposite sexes, in 3 × 1 in. corked specimen tubes, in each of which was placed a pellet of wet cotton wool. Specimens which were to be fed were also given a piece of twig covered with foodstuff, which was renewed when necessary. Each tube was then examined at least once every day, and dead specimens were removed. In this way the lengths of life, under varying conditions, of 80 specimens were investigated, the results being given in the table on p. 82.

From the table it can be seen that those specimens which were fed lived much longer than those which were not fed, and this difference is shown to be highly significant by the F-test. Statistical analysis by means of the F-test shows also that the figures show no significant difference between the length of life of the two sexes nor between those specimens which were allowed to mate and those which were not. Fed specimens deposited two or three times their volume of faecal pellets during the course of their lives, and were not seen to mate before the seventh day of life, and did not usually do so before the twelfth or thirteenth day. Mating, which lasted about 24 hours, and up to 36 hours

with some pairs, occurred up to seven times at intervals of one or two days; none of the unfed specimens was seen to copulate.

TABLE 1.

Sex	Food	Mating	Length of life in days										Average
♂	fed	mated	40	31	37	39	21	35	30	36	20	31	32·0 ± 2·19
		unmated	29	32	43	36	38	30	36	38	39	43	36·4 ± 1·54
	unfed	mated	3	3	5	3	2	3	7	5	2	4	3·7 ± 0·50
		unmated	3	3	4	3	4	4	5	6	4	4	4·0 ± 0·30
♀	fed	mated	32	50	41	44	20	37	35	28	40	15	34·2 ± 3·41
		unmated	45	46	42	28	32	34	36	33	35	42	37·3 ± 1·92
	unfed	mated	4	6	3	3	3	3	8	3	7	5	4·5 ± 0·60
		unmated	5	5	7	4	5	6	3	5	5	7	5·2 ± 0·39

These observations indicate that specimens of this species which find no food after emergence die before they are able to mate, and certainly before they can produce eggs. Unfortunately none of the fed females extruded eggs under the conditions of the experiments, but all, including those which were not fertilised, became fully gravid after about fifteen or twenty days, and a fertilised female kept under the same conditions, but in a larger container, extruded eggs on her thirtieth day of life. It therefore seems that, at least in this one species, the feeding of the adults is an essential part of the life-history; and the same would appear to apply to the whole of the Filipalpia (comprising in Britain the families CAPNIIDAE, LEUCTRIDAE, TAENIOPTERYGIDAE and NEMOURIDAE), which, unlike the Setipalpia (comprising the families PERLODIDAE and PERLIDAE), do not feed as adults (Hynes, 1941) and mature their eggs after emergence. Fully matured eggs are to be found in the last nymphal instar of the Setipalpia, but not in the Filipalpia, where they develop after emergence. With regard to mating, the absence of food cannot prevent its occurrence in all species, because males of *Capnia nigra* Pictet will, when less than twelve hours old, mate with newly-emerged females whose wings are not yet fully extended. But even in this species several days of life are necessary in order to allow the eggs to mature, and the adult female probably requires food during this period.

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THE ORIGIN OF STRIDULATION IN BEETLES

By Gilbert J. Arrow, F.Z.S., F.R.E.S.

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STRIDULATION, that is the production of squeaking or chirping sounds by friction, it is fairly well known, is very common in beetles; but it is a rather curious fact that in few, if any, of the numerous groups in which the faculty exists does it seem to prevail generally and in many it appears to be confined to a small minority of species. For example, in the Stag-beetles, in which, from their comparatively large size, it should be more easily detected than in most others, only a single species, the Chilean *Chiasognathus granti*, is known to stridulate.

Another conspicuous fact concerning the stridulatory organs of beetles is that, although rather uniform in their essential character, they may occur in almost any part of the body. Wherever two hard surfaces rub against each other in the course of the ordinary movements one is likely to find, in one kind of beetle or another, a special adaptation of the two surfaces resulting in the production of sounds more or less musical in quality. The apparatus usually takes the form of a series of parallel ridges, too fine and close together to be visible to the naked eye, set transversely to the direction of movement, so that they are plucked or scraped by a part of the opposed surface, which may be a sharp ridge or series of ridges, spines or granules. The part of the body upon which the organ is found, while it may be the same in unrelated groups, may be different in different members of the same group. Thus the stridulatory plate or file is situated upon the upper surface of the head and scraped by the front edge of the thorax in members of the unrelated families ENDOMYCHIDAE and HISPIDAE, while in certain forms belonging to the three very different families TENEBRIONIDAE, PTINIDAE and SCOLYTIDAE, it is found upon the lower side of the head and operated by the prosternum. In a genus of CARABIDAE (*Siagona*) and one of BOSTRICHIDAE (*Phonapate*) a file upon the fore-leg is rubbed against projections at the side of the prothorax; in a Cicindelid (*Oxychila*), a Lucanid (*Chiasognathus*) and a Tenebrionid (*Cacicus*) the femora of the hind-legs scrape a file upon the outer edges of the elytra; and a file beneath the elytra, rubbed by the abdomen, occurs in particular genera of CARABIDAE, PELOBIIDAE, COPRIDAE and TROGIDAE. One must suppose from this evidence of so many independent origins, combined with so apparently erratic a distribution, that the organs are not of very ancient date nor of any very vital importance. They must, however, be of some real use and benefit and not only to adult insects but to larvae as well, for their existence in a highly developed form in many beetle larvae is perhaps the most remarkable fact concerning them.

What then is the real significance of these organs? In *The Descent of Man* Darwin stated that, from analogy with the crickets, grasshoppers, Cicadas, etc., he expected to find the organs differing in the two sexes, but he was only able to conclude that " in some few Coleoptera stridulation is a sexual character." Amongst about 16 genera known to him to stridulate he found after careful investigation only two in which the organs were not the same in both sexes. Knowledge of the subject has greatly increased since Darwin wrote, the best general account in English being that of C. J. Gahan (1900, *Trans. ent. Soc. Lond.* **1900**: 433), who enumerated very many stridulating genera, belonging to more families than the number of genera known to Darwin. Many others have been discovered since and others undoubtedly remain to be discovered. A good summary has

been published by Dudich in 1920–1921, *Ent. Blätt.* **16** : 146; **17** : 136, 145. The existence of the organs in beetle larvae, announced in 1874 by the Danish entomologist Schiødte, was unknown to Darwin and evidently throws an entirely fresh light upon the problem. From the profound character of the modifications by which some of the larval organs have been produced it seems likely that they existed at an earlier period than the corresponding organs of adult beetles. For example, in the family PASSALIDAE the stridulatory plates lie at the bases of the second pair of legs, and the third pair are so entirely altered for operating the instrument that they have lost every trace of their original form and purpose, these larvae having practically become four-legged animals.

Although a few instances unknown to Darwin have been found in which a sexual difference occurs in the stridulating organs, these do not strengthen the case for regarding the faculty as serving for communication between the two sexes. The genera known to him in which male and female differ in this respect are *Heliopathes*, in which the apparatus is confined to the males, and *Oryctes*, in which the vibratory ridges are coarser in the male than in the female. I have myself [1] recorded a few other cases, especially two (*Xenodorus janus* and *Acerus davus*) of which the females are without the apparatus. Other instances were described by Gahan as occurring amongst weevils (*Cryptorrhynchus lapathi*, etc.). It is important to note that in every one of these cases, belonging to very different families of beetles, the organ is found in the same situation, viz. between the terminal part of the abdomen and the elytra. The abdomen of female beetles is apt to become distended with eggs, so that there is no exact correspondence, as in males, between its terminal part and that of the elytra and it is less capable of the rapid movements by which sound is produced. In many cases too, as in *Oryctes* and most of those just mentioned, the terminal segments are differently shaped in male and female in accordance with the different sexual functions and the method of oviposition of the female. In certain weevils described by Gahan the ends of the elytra are in contact with a different segment in male and female respectively, and the differences in the vocal apparatus described were evidently necessitated by this structural difference. The comparative fineness of the stridulatory file in the female of *Oryctes* can be seen also in various related genera but it does not seem to bear the interpretation suggested by Darwin as to the purpose of the resulting sounds. Here also the apparatus is placed at the end of the abdomen and it is almost certain that the movements of the females are less rapid than those of the more energetic males and so require a closer approximation of the vibratory ridges to produce a similar effect. Setting aside these cases of organs at the end of the abdomen, only two isolated cases of sexual difference are known, viz., *Spilispa imperialis*, in which the file is at the top of the head, and *Phonapate*, in which it is upon the fore-leg. In the former it is present only in the male and in the latter only in the female. These two remarkable exceptions are at present quite inexplicable.

It is evident that there is a great difference in this respect between beetles and such insects as the Cicadas and crickets whose vocal organs are chiefly associated with the male sex, as there is also in the volume of sound produced. Beetle voices are so feeble in comparison that only a very small fraction of the organs now known to exist can ever have been heard by human ears and it is likely that many are quite inaudible to man. Probably very few could be heard at a distance of more than a yard or so. In consequence scarcely anything is yet known as to the purpose served by them. They appear to be used at times of excitement and Mr. Hugh Main believes he has heard the female

[1] 1904, *Trans. ent. Soc. Lond.* **1904** : 719.

Geotrupes calling to the male when engaged together in provisioning their nest; but the evidence of this can hardly be considered sufficient for forming a definite conclusion. The loudest beetle voices seem to be those of the semi-social PASSALIDAE, already mentioned, which have the most highly developed of all larval stridulating organs. Ohaus has recorded in 1900, *Stettin. ent. Ztg* **61** : 164 that one of these beetles in Brazil, when confined in a vessel in his room, chirped so loudly at night that he was obliged to remove it from the room. He relates also that in breaking up a log he found and threw aside a family of these beetles consisting of larvae and adults. During his further operations he heard continual chirping proceeding from these and before leaving the spot he turned over a piece of wood lying on the ground and found beneath it the two parents and four larvae, while two other larvae were making their way to the same shelter as fast as intervening obstacles allowed, guided, as he believed, by the voices of their parents. The incident happened more than 40 years ago and no confirmation of it has yet been obtained. Other investigators who have studied the habits of the PASSALIDAE have regarded his statement as owing something to his imagination but the experiment of repeating the circumstances does not appear to have been tried. Should the fact of such intercommunication amongst the PASSALIDAE be confirmed, however, it would not throw much light upon the possession of vocal organs by other larvae. Those of *Geotrupes*, for example, lead completely solitary lives throughout the period of immaturity, each inhabiting a separate underground chamber, so that no inter-communication is possible.

Darwin recorded in *The Descent of Man* (Chapter X) that the grotesque Stag-beetle, *Chiasognathus*, in Chile, when molested assumed a threatening attitude and at the same time stridulated loudly. It is possible that loud sounds may have an intimidating effect upon enemies, but this will not explain the very feeble voices of the great majority of stridulating beetles. It seems possible, however, that the vibrations by which the sound is produced, when communicated through the exterior of a hard-shelled insect, may cause an unpleasant sensation in the mouth of the creature seizing it and the sound may serve as a warning against repetition of the attack.

Although some of these organs are very highly developed, different species show them in many stages of development, some having a comparatively coarse structure which, instead of a high-pitched note, must produce only a grating or rustling sound. The closely packed ridges towards the end of the abdomen in Dynastid beetles, which are scraped by the ends of the wing-covers, show many degrees of fineness. These no doubt represent stages in the process by which the perfected instrument has been gradually evolved, unmusical grating sounds having first resulted in all cases. Darwin considered that the slight rustling sound produced by the rubbing of the undifferentiated surfaces originally served to attract the attention of the other sex and that from its use in that way improvement gradually resulted by the operation of sexual selection. It is known, however, that the olfactory sense of insects is capable of bringing them together, sometimes from considerable distances, and to suppose that these slight rustling sounds could lead to recognition at a distance in a world full of sound is to assume the possession of an auditory sense as well developed as the olfactory sense. Of this there is little evidence. Nothing has been found in beetles resembling the supposed auditory organs of other vocal insects nor is there any reason to believe that it is the habit of female beetles of any kind either to gather at the summons of the male or to issue a summons themselves. The supposition that beetles are able to hear rests upon rather slender evidence.

A Death-watch beetle will respond to the tapping of another individual of its species but does not distinguish it from similar taps produced by man with a variety of instruments. It is likely therefore that the stimulation to which it responds is the vibration of the surface with which its feet are in contact.

It seems to me probable that many insects perform movements of different kinds for their own enjoyment, such as the cricket which chirps for hours together or the flies that hover or dance in the air, the satisfaction being found, not in the sounds that may result from the movements, but in the exercise of the muscles, as the lark or the nightingale probably finds enjoyment more in the exercise of its throat-muscles than in the music so produced, whether or not this has acquired a value of its own.

In certain beetles two stridulating-organs have been found in different parts of the body of the same insect. This is the case, according to Gahan, in the Longicorns of the genus *Plagithmysus,* and I have recorded the same thing in EROTYLIDAE and ENDOMYCHIDAE (1924, *Trans. ent. Soc. Lond.* **1924** : 134). It has also been found in Water-bugs of the genus *Corixa* that two sets of organs producing quite different sounds exist together. If the object of the organs were to produce a distinctive call-note the emission of two different sounds, whether at the same or different times, would tend to defeat it by contributing to the general confusion; but, if the sound was originally incidental only and the friction giving rise to it had a value of its own, this objection disappears. If, as it seems reasonable to suppose, satisfaction is derived from the exercise, the sense of well-being probably reflects an actual physical benefit obtained from it. Natural selection would bring about improvement of the parts concerned in a beneficial operation. The change from a comparatively irregular to an extremely regular structure of the vibratory parts may be concerned with the wider distribution of the vibrations through the chitinous shell of the insect, which may have, as I have suggested, a protective value against predacious enemies. In the case of larvae, whether solitary or not, such vibrations may conceivably serve to baulk parasites attempting to lay eggs upon them.

The sounds resulting from the movements may, although originally without significance, have eventually acquired uses differing in different cases; and, if the origin I have suggested for the organs of beetles is correct, it will also serve to explain the early stages of organs so much more vocally effective as those of crickets, grasshoppers and other insects.

STUDIES ON THE CHEMISTRY OF PIGMENTS IN THE LEPIDOPTERA, WITH REFERENCE TO THEIR BEARING ON SYSTEMATICS. 2. RED PIGMENTS IN THE GENUS *DELIAS* HÜBNER

By E. B. FORD, M.A., B.Sc., F.R.E.S.

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Delias is the largest genus of the PIERIDAE, comprising 159 known species. Its systematics have been studied in exceptional detail, for the results embodied in *Lepidopterorum Catalogus* (Talbot, 1932–35) are greatly amplified in Talbot's monograph (1928–37). The species are almost entirely Indo-Australian in distribution, though a few enter the south-eastern part of the Palaearctic Region. Their white and yellow pigments contain no anthoxanthin (Ford, 1941), but two types of red pigment are distributed among them. This is a rare colour in the PIERIDAE, being found only in a few other genera, notably *Pereute* and *Archonias*.

No difference between the two red pigments of *Delias* can be detected by the eye. However, they are easily distinguished by other means. One (" pigment D ") is converted to a bright yellow shade by strong mineral acids (*e.g.* hydrochloric acid) and reconverted to red by alkalis (*e.g.* ammonia). The other (" pigment E ") is almost unaffected by acid. Most of the species that are marked with red possess one or the other of these substances alone, type D being much the commoner. In two of them, however, both types seem to be present together, so that their red areas turn orange on exposure to acid owing, apparently, to the mixture of the yellow so obtained with unaltered red.

Hopkins (1895) described the solubilities and other reactions of three types of red pigment in the Lepidoptera. One of them is that found, for example, in the Vanessidi. It may for convenience be called " pigment C." Acids cause it to assume a duller tone, and the colour is not entirely restored by subsequent treatment with an alkali. It is rapidly soluble in hot water or in an aqueous solution of ammonia, and it does not react to the murexide test for uric acid.

The second of these pigments (" pigment A ") was originally described by Perry-Coste (1890–91). It is changed to bright yellow by hydrochloric acid and reconverted to red again by an alkali, both reactions taking place with great rapidity. Hopkins showed that it is soluble only to a very slight degree in hot water or dilute alkalis, and that it does not give the murexide reaction. This pigment is widespread in the Lepidoptera, and its occurrence and genetics have been discussed by Ford (1937). It is responsible for the red colours of many groups : in particular, the ARCTIIDAE, the ZYGAENIDAE and, in the PAPILIONIDAE, for those of *Polydorus* (except the Polydamas Group) and of *Graphium*; but not of *Papilio*, save in two exceptional instances out of fifty-two species tested (Ford, 1940).[1]

The third red pigment examined by Hopkins is that occurring in the majority of the genus *Delias* (" pigment D "); he made a special study of it in *D. eucharis* Drury. It is rapidly soluble in hot water and dilute alkalis, and gives the murexide reaction. However, Hopkins did not mention that it reacts with acids and alkalis in the same way as that last described (pigment A), which he had studied in *Polydorus aristolochiae* F. For, when the wings of any *Delias* species possessing pigment D are fumed with hydrochloric acid, the red areas are converted to bright yellow, while they can be reconverted to red by an alkali. There is in fact nothing to distinguish between pigments A and D when sub-

[1] My subsequent work has reduced the proportion of exceptions in *Papilio* to 2 out of 107 species.

jected to this test, though their other reactions demonstrate that they are widely different.

As already mentioned, I now find that a red pigment which does not react in this way also occurs in *Delias*, but much more rarely. This may be called " pigment E." It indeed becomes very slightly paler on exposure to hydrochloric acid, but it cannot be changed from bright red by this means. This is still true after an exposure of 14 hours, when the insect is becoming limp : similar treatment would convert the other pigment of *Delias* (pigment D) to a yellow shade in five minutes. In other respects, however, the two types have much in common, for pigment E, which remains red on exposure to acid, is none the less rapidly soluble in hot water and dilute alkalis, and gives a positive murexide reaction. This is in accord with the view of Hopkins that the pigments of the PIERIDAE (except the black) are all uric acid derivatives. The species which I used for the solubility tests and the murexide reaction was *D. acalis* Godart (= *thysbe* Cramer).

I am much indebted to Mr. J. R. P. O'Brien for his kindness in working out the following technique to make the murexide test suitable for the present investigations. The red areas of the wings are cut into small pieces and soaked in concentrated nitric acid (sp. gr., 1·18) for half an hour. The liquid is then removed to a small porcelain dish by means of a teat-pipette, and evaporated to dryness on a water-bath. A reddish residue is left if the reaction is likely to be positive. After cooling, strong ammonia solution is added gradually by means of capillary tubing, when an ordinary murexide reaction is obtained if the pigment contains uric acid compounds. That is to say, a reddish-violet colour is produced. If the amount of pigment is small, this may be extremely transient, and a careful watch for it must be kept as the ammonia is added.

A difficulty arises when red scales are present on one side of the wing only, and white on the other. Since the white pigment of the PIERIDAE gives a positive murexide reaction (Hopkins, 1895), it must not be allowed to contaminate the material to be tested. In these circumstances, it is necessary to remove the scales from one surface of the wings. I am much obliged to Mr. E. Taylor for bringing to my notice a technique admirably suited to this purpose. It is due to Landois (1866). Celloidin is dissolved in equal parts of absolute alcohol and ether, to give a solution of the consistency of a thin syrup. Several drops are poured on to a sheet of paper and spread evenly over an area of the required size. The wing, which has previously been cut from the body, is then quickly laid upon the liquid celloidin and pressed gently into it. The surface to be preserved must of course be placed upwards. The solution is allowed to dry thoroughly, for at least an hour, when the wing-membrane can be pealed off intact. It will then be found that the scales have adhered to the celloidin, leaving the wing completely diaphanous on one side. The red areas can now be cut out. In a number of species, however, black scales are interspersed with the red. No error is introduced here, since Hopkins found that the black pigment of the PIERIDAE does not give a murexide reaction, a fact which I myself confirmed.

It is of course not possible to examine the solubility of the pigments or to apply the murexide test widely, since these procedures destroy the specimen, and many of the species are rarities which must not be damaged. However, in addition to *Delias acalis* and *D. eucharis* Drury already mentioned, I have demonstrated the solubility of the red pigments, and obtained a positive murexide reaction from them, in *D. nigrina* F., *D. harpalyce* Donovan, and *D. mysis* F. This sample is widely scattered through the genus, so that there is no reason to doubt that the red pigments of *Delias* are uniform in their degree of solubility and response to the murexide test.

Pigments A and D are converted to bright yellow by nitric acid, as they are with hydrochloric acid, and restored to red by ammonia. However, when kept somewhat longer in nitric acid the scales become colourless, and this effect cannot be reversed by an alkali. Partial restoration only takes place if the decolorisation has started. Pigment E is as easily decolorised by nitric acid as are A and D but it remains red throughout the process, for the red scales gradually lose their colour without passing through a yellow stage. The contrast between the two types of red pigment in *Delias* is very striking when subjected to this treatment.

I may add for completeness in comparison that the red pigment occurring in *Papilio*, and in the Polydamas Section of *Polydorus*, is distinct from any of these. This may be called " pigment B." It resembles that of the Vanessidi (pigment C) to the extent that it does not give the murexide reaction and is not converted to bright yellow by an acid, but it differs in being insoluble in hot water and dilute alkalis. Probably therefore it is a melanin. I have studied its reactions with acids and alkalis in a large number of species (Ford, 1940), and have examined its solubility and applied the murexide test in *Papilio anchisiades* Esper, *P. torquatus* Cramer, *P. polytes* L. (female form *romulus* Cramer), *P. aegeus* Donovan, and *Polydorus polydamas* L.

The distributions and reactions of these red pigments are given in Table 1. I have arbitrarily assigned distinguishing letters to them for convenience; Types A and B have already been so called in a previous work (Ford, 1940). None of these pigments can be dissolved in a fat-solvent (*e.g.*, carbon bisulphide), so that they do not appear to include any of the carotin group.

TABLE 1.

The occurrence and reactions of some red pigments in the Lepidoptera.

	Occurrence	Changed to yellow by HCl, restored by NH₃	Solubility in hot water and dilute alkalis	Murexide test
A	*Graphium* *Polydorus* (except Polydamas Group) ARCTIIDAE ZYGAENIDAE	yes	very slight	negative
B	*Papilio* *Polydorus* (Polydamas Group only)	no	insoluble	negative
C	Vanessidi	no	great	negative
D	*Delias* (except Pasithoe Group)	yes	great	positive
E	*Delias* (Pasithoe Group)	no	great	positive

Seventy-four of the known species of *Delias* possess pigments which are distinctly red. I have been able to examine seventy-one of these. The remaining three (*lemoulti* Talbot, *ellipsis* Joannis, and *mayerhoferi* O. Bang-Haas) are not accessible owing to war conditions. Fortunately the test required to distinguish between the two pigments of *Delias* does not damage the specimens. Indeed some of those studied are species of great rarity, including even unique types (*wollastoni* Rothschild, *klossi* Rothschild, *eileenae* Joicey & Talbot).

The results of this investigation are given in Table 2, in which the species are arranged according to Talbot (1928–37). It will be observed that all the *Delias* examined possess pigment D except the Pasithoe Group, in which none does so.

TABLE 2.

The distribution of two types of red pigment, D and E, in the genus *Delias*.

	Species	Group		Species	Group
D	*lecerfi* Joicey & Talbot	Stresemanni	D	*nigrina* F.	Nigrina
D & E	*sagessa* Fruhstorfer	Geraldina	D	*wollastoni* Rothschild	,,
D	*microsticha* Rothschild	,,	E	*henningia* Eschscholtz	Pasithoe [1]
D	*hypomelas rubrostriata* Joicey & Talbot	,,	E	*woodi* Talbot	,,
D	*thompsoni* Joicey & Talbot	,,	E	*erithoe* Boisduval	,,
D	*castaneus* Kenrick	Bornemanni	E	*pasithoe* L.	,,
D	*caroli* Kenrick	,,	E	*acalis* Godart	,,
D	*bornemanni* Ribbe	,,	E	*ninus* Wallengren	,,
D	*nais* Jordan	,,	D	*klossi* Rothschild	Clathrata
D	*iltis* Ribbe	Iltis	D	*descombesi* Boisduval	Belisama
D	*mesoblema* Jordan	,,	D	*splendida* Rothschild	,,
D	*bakeri* Kenrick	,,	D	*belisama* Cramer	,,
D	*callista* Jordan	,,	D	*levicki* Rothschild	,,
D	*hapalina* Jordan	Weiskei	D	*zebuda* Hewitson	,,
D	*campbelli* Joicey & Talbot	,,	D	*eumolpe* Smith	,,
D	*phippsi* Joicey & Talbot	,,	D	*madetes* Godman & Salvin	,,
D	*weiskei* Ribbe	,,	D	*aruna* Boisduval	,,
D	*callima* Rothschild & Jordan	,,	D	*diaphana* Semper	,,
D	*marguerita* Joicey & Talbot	,,	D & E	*aganippe* Donovan	,,
D	*kummeri* Ribbe	Kummeri	D	*harpalyce* Donovan	,,
D	*ligata* Rothschild & Jordan	,,	D	*eileenae* Joicey & Talbot	Dorimene
D	*isocharis* Rothschild & Jordan	,,	D	*sacha* Smith	Isse
D	*alepa* Jordan	,,	D	*candida* Vollenhoven	,,
D	*dixeyi* Kenrick	,,	D	*eucharis* Drury	Hyparete
D	*bothwelli* Kenrick	,,	D	*hyparete* L.	,,
D	*joiceyi* Talbot	Nigrina	D	*rosenbergi* Vollenhoven	,,
D	*oryntion* Godman & Salvin	,,	D	*mitisi* Staudinger	,,
D	*dohertyi* Oberthur	,,	D	*periboea* Godart	,,
D	*prouti* Joicey & Talbot	,,	D	*fasciata* Rothschild	,,
D	*eximia* Rothschild	,,	D	*sambawana* Rothschild	,,
D	*duris* Hewitson	,,	D	*poecilea* Vollenhoven	,,
D	*funerea* Rothschild	,,	D	*ceneus* L.	,,
			D	*timorensis* Boisduval	,,
			D	*mysis* F.	,,
			D	*euphemia* Smith	,,
			D	*salvini* Butler	,,
			D	*bagoe* Boisduval	,,
			D	*schoenbergi* Rothschild	,,
			D	*argenthona* F.	,,

[1] The Pasithoe Group was called the "Aglaia Group" by Talbot, for the species from which it is named (*D. pasithoe* L.) was known until recently as *D. aglaia* L. In addition, the prior name *acalis* Godart has now been substituted for *thysbe* Cramer.

The red colours of *Delias* are usually of a bright clear shade, but in some the markings on the underside are of a rich maroon, as in *bornèmanni* Ribbe, *nais* Jordan, *callima* Rothschild & Jordan, and others. On exposure to acid this becomes converted to a yellowish-grey, the original tint being restored by ammonia. Examination with a lens shows that this colour is produced by a mixture of red and black (or grey) scales, and that the former become yellow after treatment. Moreover, the red pigment can be extracted from the wings by means of a dilute alkali, giving a reddish-tinted solution similar to that obtained from the bright red spots of other species. This has been demonstrated in each of the three species named. It is clear therefore that the maroon-coloured

forms may be treated as red-marked species, and that their red pigment is of type D.

Two species, however, are peculiar in that they seem to possess both kinds of red pigment (D and E). These are *sagessa* Fruhstorfer and *aganippe* Donovan. Their red markings are therefore converted only to an orange shade by hydrochloric acid. Mr. G. Talbot informs me that he had come to the conclusion, upon structural grounds, that these are both rather exceptional : so much so that he had placed them in their respective groups somewhat tentatively. Thus the evidence derived from a study of their pigmentation is in accord with the view, based on other considerations, that these are isolated species.

Mr. Talbot tells me that having regard to the additional information presented here, he would now separate *aganippe* Donovan from the Belisama Group and place it in a group by itself (forming a new " Aganippe Group ") between the Belladonna and the Pasithoe Groups. The Belladonna Group comprises yellow-marked species none of which possesses red pigments, consequently it is not included in the present analysis. It occupies a position between the Nigrina and the Pasithoe Groups. On the other hand, *sagessa* Fruhstorfer is better retained in the Geraldina Group, for this contains some very distinct forms. Though an isolated species, it is on structural grounds more closely allied to the others of its group than is *aganippe* Donovan.

During the course of this work, two suggestions have been made to me which, though reasonable, are incorrect. They must briefly be mentioned lest they should be raised again.

First, it chances that throughout the Pasithoe Group, in which pigment E occurs alone, the red areas occupy the base of the hind-wings only ; while among the other Groups, in which pigment D is present, red sub-marginal spots and red bands crossing the disc of the hind-wings are frequent on the underside. The view was expressed that red spots occupying distinct regions of the wing might have different chemical constitutions. A survey of the genus makes such a concept untenable. Red marks are found at the base of the hind-wings on the underside in many species outside the Pasithoe Group, such as *castaneus* Kenrick, *nigrina* F., *descombesi* Boisduval and numerous others, yet here they are due to pigment D ; while, as already mentioned, pigment E is present (in addition to D) in the red sub-marginal spots of *D. sagessa*. The distribution of the two types of red pigment in *Delias* is not related to their position on the wing.

Secondly, it was suggested that the failure of the red markings of the Pasithoe species to turn yellow on exposure to acid might be due to a difference not in their red pigment but in their scales, which may be impermeable. This is not correct, and for several reasons. Pigment D is changed from red to yellow by exposure for a few minutes to a concentrated atmosphere of hydrochloric acid. In the Pasithoe Group the pigment remains red after a similar exposure lasting for fourteen hours. It cannot be supposed that the degree of chitinisation of the scales could make so great a difference to the passage of the gas, especially as the red pigment in the Pasithoe Group is as easily soluble both in hot water and dilute alkalis as it is in the other species of the genus. However, the behaviour of these pigments when exposed to nitric acid appears to be decisive. As already mentioned (p. 9), both are decolorised by this means, pigment D passing through a yellow stage during the process, while E does not. It is clear therefore, on the one hand, that the acid reaches pigment E, and on the other that it does not turn it yellow. Thus it must be in the constitution of their red pigments, not in the degree of permeability of their scales, that the Pasithoe Group differs from the majority of the *Delias* species.

The present classification of *Delias* is largely due to the work of Talbot, and the distribution of the two types of red pigment occurring in that genus proves to be strictly related to it. Chemical considerations therefore support this classification on grounds wholly distinct from those upon which it had been constructed.

During the course of this work I have received valuable help, which I gratefully acknowledge, from Prof. G. D. Hale Carpenter, Mr. N. D. Riley, Prof. R. A. Fisher, Mr. G. Talbot, Mr. J. R. P. O'Brien, Prof. E. S. Goodrich, and Mr. A. G. Gabriel.

SUMMARY.

1. Five types of red pigments have now been distinguished in the Lepidoptera. Their distributions and reactions are given in Table 1.

2. Two of these red pigments (called, for convenience, D and E) occur within the genus *Delias*. These are both soluble in hot water and dilute alkalis, and give a positive murexide reaction. No difference between them can be detected by the eye, but they can be distinguished by treatment with acids. One (pigment D) is converted to a yellow shade by hydrochloric acid, and is then reconvertible to red by ammonia. The other (pigment E) does not become yellow on acidification.

3. Pigment D is present in all red-marked species of *Delias*, except those of the Pasithoe Group, from which it is without exception absent (Table 2).

4. Two species (*sagessa* Fruhstorfer and *aganippe* Donovan) appear to possess both types of red pigment (D and E), so that their red markings become orange on acidification. In this respect they are distinct from the others of their respective Groups. Also Mr. G. Talbot informs me that he had found on structural grounds that these two species are somewhat isolated.

5. *aganippe* Donovan should now be placed in a new group by itself (the Aganippe Group) between the Belladonna and the Pasithoe Groups. *sagessa* Fruhstorfer can be retained in the Geraldina Group, as this already contains some very distinct forms.

6. The two types of red pigment (D and E) found in *Delias* are not distributed at random according to the present arrangement of the species, but their occurrence is strictly related to it. Chemical considerations therefore support the classification of this genus on grounds wholly distinct from those upon which it had been constructed.

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ACTIVITY OF *GLOSSINA PALLIDIPES* AT NIGHT (DIPTERA) [1]

By T. W. CHORLEY, F.R.E.S., and G. H. E. HOPKINS, M.A., F.R.E.S.

VANDERPLANK has shown that very much larger numbers of *G. pallidipes* may be captured on days following dark nights than on those following moonlight nights. He has drawn from this fact the reasonable inference that "*G. pallidipes* feeds on moonlight nights and does not feed so freely, if at all, on dark nights." He reports two direct observations which show that *G. pallidipes* is active at night.

The observations now recorded are very incomplete but seem worth publishing because they provide a certain amount of direct confirmation of Vanderplank's inference, and because of the dearth of published observations on this very important point in the biology of *G. pallidipes*. Owing to pressure of other work, and the fact that the main object of the observations has been attained, an opportunity to carry the observations farther is not likely to arise.

The work was carried out at Wokola, in Buruli county, 88 miles due north of Kampala. This portion of Buruli has recently become heavily infested with *pallidipes*, and an important route of the cattle-trade has thereby become unusable. The statements, to be found in most old books about Africa, to the effect that cattle can safely be taken through belts of *G. morsitans* if the journey is carried out at night, suggested the necessity of testing whether the same might be true of *G. pallidipes*, though the known partly-crepuscular habits of the latter species gave small grounds for expecting a favourable result.

The "fly-round" for the observations was a 2½-mile strip of the road leading northwards from Wokola. This strip runs through samples of all the main vegetational types found in northern Buruli, including dense thicket, savannah and almost treeless wet-weather swamps ("vleis").

The experiments were carried out with an ox as bait, to which a "kongoni-screen" was added after the first night. The screen is a dry skin of a kongoni or hartebeest (*Alcelaphus jacksoni*), folded over a pole and carried by two porters in such a way that the sides of the skin hang about six inches above the ground. The use of the screen was partly to increase the size of the bait and partly to test the attractiveness of the screen against that of an ox so that the screen might be substituted for an ox in future work if it were found to be sufficiently attractive. The same ox and the same trained staff were used for all the observations.

The times given in these notes are East-African Standard Time and the watch was checked daily by the B.B.C. time-signal; the 24-hour notation is employed.

OBSERVATIONS ON MOONLIGHT NIGHTS.

These observations were carried out on the nights of the 8th–9th July and 9th–10th July 1941. On the first night work began at 19.25, about three-quarters of an hour after sunset and as the moon was rising, and went on until midnight; on the second night work began at midnight and went on until 6.15.

On both occasions there was a very bright full moon and a cloudless sky.   There was no wind on either occasion.

The method employed was as follows :—Two untrained porters went about eight yards ahead, beating the bushes on each side of the road in order to disturb resting tsetse by imitating the way in which a moving herd of cattle would brush against the bushes.   The ox followed, flanked by an African Entomological Observer on one side and T. W. C. on the other, and followed by the herdsman. Then came two more porters, followed by an African Tsetse-Surveyor; after the first night these latter porters carried the kongoni-screen.   All three trained members of the party were armed with tsetse-nets and electric torches, and the torches were flashed on for a few seconds at intervals of two or three minutes to enable a search for tsetse to be made; on these occasions the ox was sometimes halted and sometimes not.   Tsetse could easily be seen, either on the screen or on the ox, by the aid of the torch.   No tsetse other than *G. pallidipes* were encountered, nor is any other species known to occur in the area, which has been rather thoroughly examined.

On the return journey on the first night a lighted hurricane-lamp was carried a few yards in front of the ox, since Africans driving cattle along a road at night would normally use a lamp of this kind, and it was thought possible that tsetse might be attracted by the light.   The presence of the lamp made no appreciable difference in the numbers of tsetse observed and at no time were they seen flying round it.

The very long time (more than four hours) occupied on the first night by the double journey of five miles resulted from the frequent halts to collect tsetse, the exasperatingly obstinate dislike of a single ox to being driven along a road at night, and the strenuous objection of the ox in question to permitting tsetse to be caught on its person.   The use of the screen improved matters considerably, because it gave no trouble in the two latter respects and a large proportion of the tsetse disturbed from the ox promptly settled on the screen.   Tsetse which settled on the ox were recorded, allowed to feed to make them more amenable to being caught, and were then caught if possible.

The results of the two rounds carried out on moonlight nights are shown in Table 1, and those of a round made in daylight, on the evening of the 10th July, in Table 2.   The latter round was carried out as a control and was begun at 16.30, thus covering the time of maximum daylight activity of *G. pallidipes*; both ox and screen were used and the route was the same as at night.   There was a little wind at first.

It will be noted from these tables that activity went on throughout the night and that both sexes were concerned.   The number caught or seen on the moonlight rounds (62) is little smaller than the 76 observed on the daylight traverse, and the difference is possibly accounted for by the greater difficulty of seeing tsetse at night; for the same reason the " swarm " must be ignored as it would certainly not have been seen at night.   It seems unlikely that the capture of 42 specimens prior to the daylight round would have had an appreciable effect on the size of the tsetse-population in the area.   A further point of some interest is the marked increase of activity shown in Table 2 as dusk set in.   This illustrates clearly the more or less crepuscular habits of the species.

Observations on a Dark Night.

The observations on activity of *G. pallidipes* on a dark night were made, on the same route at Wokola and under exactly the same conditions, on the

moonless night of the 23rd–24th July 1941. Unfortunately they do not permit of exact comparison with the earlier observations because there were obviously far fewer tsetse on the round on this occasion, a daylight search with the ox and screen from 16.30 to 18.45 on the afternoon of the 23rd only resulting in seven *pallidipes* (which were purposely not caught) being seen. The cause of this reduction is not known, but two possible contributory factors were noted : a gang of labourers had been working on the road for several days previously and the tsetse had fed freely on them and were presumably not hungry, and the herd of buffalo observed on the earlier occasion had apparently moved away ; it is known that buffalo are a very favourite food of *pallidipes* and that the fly sometimes move out of an area with a herd of buffalo. The night of the observations was dark but with a clear starry sky until about 2.30, when it clouded over and became pitch-dark.

The results of the search were so meagre that a table is unnecessary. Work started at 19.30 and continued, with rests from 22.30 to 23.30, 2.30 to 3.30 and 5.30 to 6.00, until 6.30 (half an hour after dawn). A female *pallidipes* was seen on the ox at 19.40 and caught on man at 20.20, a male was caught on man at 3.55, when it was extremely dark, and two were seen at 6.10, of which one fed full on the ox. The figures are too small to show more than that there is a certain amount of activity by *pallidipes* even on a very dark night.

General Points.

The favourite site of attack by a given species of tsetse has an important bearing on methods of catching the species concerned. It was noted that the great majority of the *pallidipes* seen during these observations settled low down, whether on screen, ox or man, but actual figures are available only in the case of man. On the two moonlight nights 21 specimens were observed on man, of which 17 were on the legs, 2 higher up, and in 2 cases the site was not recorded.

A further important point is whether the tsetse were actually feeding at night. Of the ten specimens of *pallidipes* caught or seen on the ox on the two moonlight nights, at least four fed full (at 20.50, 22.25, 22.55 and 1.55) ; a blood-filled male was captured on an African's leg at 5.50, two hours after the ox had been left behind.

The observations also give some information on the relative attractiveness of ox, man and screen. On the moonlight nights 21 specimens were observed on the ox as against 14 on six men (no collections were made from the two front porters). During periods when ox and screen were both present, 10 were seen on the ox and 12 on the screen. During periods when the screen was in use, 23 tsetse occurred on the screen as against 8 on man. The figures are small, and too much stress must not be laid on them, but they suggest that ox and screen are of about equal attractiveness, while man is much less attractive than either. In the daylight round on the 10th July the differences were greater, especially as between man and either of the other baits : 40 specimens were observed on the ox, 29 on the screen and 2 on man. This observation should not be mis-construed as an indication that *G. pallidipes* is not attracted to man : it is well known that man is not a preferred food of this tsetse but he is undoubtedly very attractive to the species in the absence of the preferred sources of blood. One of us (G. H. E. H.) carried out a tsetse survey in the Lambwe valley, in the south-western corner of Kenya, in 1929; the large herds of buck normally to be found there had mostly left owing to the great height of the grass at that season, and the *pallidipes* were so hungry that five or six would be biting each

member of the party simultaneously whenever the bush-cover in which the tsetse harboured was approached. So voracious were they that they could easily be caught with one's fingers as they sucked blood.

TABLE 1.

Showing particulars of *G. pallidipes* caught or seen on a double journey of 2½ miles on moonlight nights; observations before and after midnight are on different nights. Specimens caught are not also recorded as seen. Observations went on continuously but only those occasions on which tsetse were seen are recorded.

Time	Caught	Seen	Remarks
19.35	1 ♂	1	
19.45	Nil	1	
20.25	2 ♀	1	
20.40	Nil	2	
20.50	Nil	1	
21.10	Nil	1	
21.20	1 ♀	Nil	
21.35	Nil	Nil	End of round. Bush very dense both sides of track.
21.40	—	—	Return journey begun.
22.25	Nil	1	
22.35	1 ♂	Nil	
22.55	Nil	1	
23.00	1 ♂	Nil	
23.05	—	—	Camp reached; no light used.
23.30	2 ♂, 2 ♀	2	Caught or seen while tethering ox.
0.40	1 ♀	Nil	
0.50	1 ♂	Nil	
0.55	1 ♂, 1 ♀	1	
1.15	3 ♂	1	
1.30	1 ♂, 1 ♀	Nil	
1.45	1 ♂	1	
1.55	Nil	1	
2.05	—	—	End of outward round. Screen sent on 50 yds. in front of ox.
2.25	1 ♀	Nil	
2.30	Nil	1	
2.40	1 ♂, 1 ♀	Nil	
2.45	Nil	1	
2.55	1 ♂	Nil	A herd of buffalo stampeded and the porters with the screen rejoined the main party.
3.00	2 ♀	Nil	
3.10	1 ♀	1	
3.20	1 ♂	Nil	
3.30	1 ♂	Nil	An hour's rest; ox left at camp.
4.45	2 ♀	Nil	
5.05	Nil	1	
5.10	1 ♂, 1 ♀	Nil	
5.15	3 ♂	Nil	
5.17	2 ♂	Nil	
5.25	1 ♂	Nil	
5.35	Nil	1	
5.50	2 ♂	Nil	Birds starting to call.
6.00	1 ♀	Nil	Dawn breaking. Work ceased.
TOTALS	25 ♂, 17 ♀	20	

TABLE 2.

Showing specimens of *G. pallidipes* observed on a daylight traverse of the same route. All other conditions as in Table 1.

Time	Caught	Seen	Remarks
16.30	Nil	3	
16.45	1 ♂	5	
16.47	1 ♀	Nil	
16.50	Nil	3	
17.00	1 ♂	2	
17.05	3 ♂	1	
17.15	1 ♂	2	
17.20	Nil	2	
17.37	Nil	1	Wind dropped.
17.40	—	—	End of route; return journey begun.
17.50	Nil	1	
17.55	1 ♂	3	
18.00	Nil	3	
18.10	1 ♀	4	
18.15	1 ♂, 1 ♀	3	
18.20	3 ♀	1	
18.30	2 ♂, 10 ♀	1	
18.35	3 ♂, 2 ♀	" Swarm " following party	
18.40	2 ♂, 3 ♀	4	
TOTALS	15 ♂, 21 ♀	39 (+ " swarm ")	

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BOOK NOTICE.

A lot of insects. Entomology in a suburban garden. By Frank E. LUTZ. pp. [ix] + 304, illust. 8vo. New York (G. P. Putnam's Sons) (1941). Price $3.

The preface to this book states : " This book is largely a story of American Museum of Natural History expeditions and laboratory experiments. To be sure, these ' expeditions ' took me at most only a few feet from our house and frequently lasted only a few minutes. The ' laboratory ' was sometimes in our cellar, sometimes in one of our flower beds or on the lawn."

The author is the Curator, American Museum of Natural History, and this book is the story of the insects which visited his " estate " of some 75 feet by 200 feet near the centre of an American suburban town. In a talk with his Director, Dr. Lutz expressed the opinion that at least 500 different kinds of insects either lived on or visited his own garden. This caused some incredulity and as the result of some years' observations " he recorded no fewer than 1402 species of 26 different orders." Nor is this the result of making the garden especially attractive to insects at the expense of other interests, for the author is able to record that during the period under discussion he entered his garden for 4 consecutive years in a " garden contest " and won a " certificate of achievement "; 2 bronze medals for second place; and a silver medal for first place. The chapters of the book are entitled : A lot of insects; A visitor from the tropics; Migrating butterflies; Migrating locusts; Blister beetles; Lady beetles; Lions, ant- and aphis; Plant-lice and relatives; An English guest and some of his relatives; A Chinese guest and a walking stick; Insects' commission; Our " domestic " bee; Bumble bees; Ants; " Wasps " and wasps; Termites; Tiger beetles; The tent caterpillar; Butterflies; Moth census; Gipsy and brown-tail moths; Beetles; Aquatic pets; True flies; Adding up; In addition; and Index.

The book is delightfully presented and well illustrated.

THE FOOD AND WATER REQUIREMENTS OF *PTINUS TECTUS* BOIELDIEU (COLEOPT., PTINIDAE)

By N. E. HICKIN, Ph.D., F.R.E.S.

INTRODUCTION.

Ptinus tectus Boieldieu has been known to infest a very wide range of substances in this country for well over thirty years. It was originally introduced from Tasmania through commerce and has spread rapidly through Europe. In recent years its range has extended northwards so far as Norway and Finland and it has been recorded fairly extensively in America.

The range of materials that have been attacked by the larvae and in which complete life-cycles have been reared is remarkable. Both vegetable products of high carbohydrate content and animal products of high protein content have been recorded as being infested by the larvae. Grain products, the associated debris and the various cattle foods in which the main constituents are grain products and crushed oil seeds, appear to be the materials most commonly infested. Hayhurst's (1) list of materials from railway warehouses in which adults have been collected contains ninety-six types of such foodstuffs and twelve of them contained larvae. Dried fruit and fruit products such as figs, nutmegs, sultanas, dried apricots and cacao are also extensively attacked. A third group of vegetable substances, which are often recorded as being infested by this species, can be classed as " drugs." Capsicum is frequently attacked, the larva eating the pericarp and leaving the epicarp and seeds uneaten. Cayenne pepper, ginger and leaves and flowers of *Hyoscyamus niger* and *Datura stramonium* also are recorded as larval foodstuffs.

The animal products that are often attacked are dried meat, fishmeal, dried fish, crushed crab, casein and museum specimens of insects. Great damage is done to consignments of industrial casein. Besides the products listed above, the damage to wooden parts of grain elevators, conveyors, etc., occasioned by the larvae hollowing out a position for the cocoon is often considerable.

BIOLOGY.

A number of investigators have reared *Ptinus tectus* in the laboratory. Scholz (2) reared in dried meat a brood which took approximately seven months to pass through the life-history. Von Lengerken (3) reared the species in experimental poultry foods and discussed the choice of place of pupation. Friederichs (4) reared several broods in fish food (which was probably crushed crab) and gave an account of the biology. Fahmy (5) has given an account of the morphology and anatomy of larva and adult and of several aspects of the biology. In particular, the conclusions from his experimental attempts to rear the species in absolutely air-tight containers are interesting. In no case were his attempts successful and thus in the records of this species having bred continuously in " tightly-corked " bottles one must assume that the latter were not hermetically sealed and gas exchange for adequate respiration was possible through diffusion. König's (6) description of the biology of *Ptinus tectus* is the most complete. Considerable emphasis is laid on the

various aspects of the phenomenon of brachyptery which is shown by this species.

In none of the rearing experiments carried out by the investigators cited above was an accurately controlled temperature together with foodstuff in equilibrium with a controlled relative humidity maintained. This disability was removed in the series of rearing experiments which are described below.

Identification. A systematic account of the PTINIDAE of economic importance has recently been published by Hinton (10). *P. tectus* adults are approximately 3 mm. in length but a certain variation in size was observed among the several thousands which I reared. Several individuals were little more than 2 mm. in length, whereas others were over 4 mm. It may be mentioned that the size of the adult is no indication of sex. Of the six smallest adults which were bred, four turned out to be males and two to be females. On the other hand, some males were exceptionally large. No external differences between the sexes has so far been observed. Macropterous types frequently showed the tips of the wings projecting from the distal end of the elytra.

Adult sex ratio. During the experiments on *P. tectus* a total of 1493 adults was sexed by boiling in caustic potash solution and subsequent dissection of the genitalia with a fine needle. Of this total 795 were found to be males and 698 females, giving 46·8% females and 53·2% males. Fahmy (5) dissected 143 adults and found 48·3% females and 51·7% males.

Habits. The adults run quite rapidly, but when investigating foodstuffs, damp spots, or other adults they move more slowly and deliberately and keep moving their antennae all the time. Only once was any attempt at flight observed. On this occasion a beetle was being transferred from one receptacle to another on a folded piece of paper when it commenced to run about on the paper in an excited manner. When it arrived at the highest point of the paper it opened its elytra and spread its wings. It did not vibrate them, however, and after pausing for about half a second it apparently lost its balance, toppled over, and closed its elytra. This behaviour was repeated four times before it became quiescent. This individual was of a large macropterous type.

All adults readily feign death when disturbed. The legs are held closely to the thorax and abdomen, whilst the antennae are folded back down the ventral surface. The position of legs and antennae during feigned death is exactly that occupied in the pupa. Usually, gentle breathing will cause the beetle to move and if continued it will commence to run. A dead adult is easily differentiated from one feigning death, for its legs are held stiffly erect and the antennae are invariably in a forward position.

The adults are negatively phototropic. When in the light, they shelter under anything convenient, and if confined with a soft foodstuff such as flour, they burrow fairly deeply into it. If a number of adults are confined together they invariably cluster together on the darkest side of the receptacle. Young larvae also, if sifted out of their foodstuff, will immediately try to burrow under debris, etc. On the other hand, the fully fed larvae do not shun light when seeking a position for constructing a cocoon, as they will often crawl considerable distances through lighted areas when searching. In addition they will often construct a cocoon utilising the glass wall of the culture cage as one of its sides even though by so doing light is allowed to fall on the occupant.

A point which should be observed by investigators using open petri dishes

as breeding receptacles is that *P. tectus* adults can crawl up vertical glass walls if they are damp or dusty, but not if they are kept dry and polished. The adults readily drink water. If a piece of wet cotton wool is offered to them they immediately plunge their mandibles into the moisture and drink. Whilst drinking the antennae are held back over the thorax.

A character which *P. tectus* shares with several other species of PTINIDAE, in larvae and adults, is resistance to periods of cold. Broods of this species are recorded as surviving adverse winter conditions of temperature in an unheated room, when, for three separate weeks, the temperature was below 0° C. and falling to — 2° C. on two occasions (Mansbridge (7)). The habit of burrowing in loose foodstuffs and debris may help to protect these insects from extreme cold, and an experiment was carried out by me to test the resistance of *P. tectus* to cold—no protection being available. Groups of twenty larvae and twenty adults were confined in culture cages and hung up out of doors during December 1938 for seven days and nights. During this period severe winter conditions were experienced, the lowest temperature recorded being — 8° C. and the highest + 2° C. The larvae were quiescent and the adults torpid (not, however, in the death-feigning attitude). After twelve hours at 15° C. both the larvae and adults had recovered. The larvae afterwards developed into normal adults, and the adults used in the experiment afterwards laid eggs.

Experiment. In the experimental work which follows, the influence of a range of foodstuffs on the viability of *P. tectus* was determined by noting the population increase and length of life-cycle. Each of the foodstuffs tested was in equilibrium with a range of relative humidities. The duration of the pupal stage at different relative humidities was also tested.

MATERIALS AND METHODS.

Stock. A stock of *P. tectus* was obtained from the Imperial College Biological Field Station, Slough, through the kindness of Dr. O. W. Richards. These were living in mixed foodstuffs containing crushed maize and oatmeal. Fresh stock cultures were commenced, using wholemeal flour (unsieved) in 1-lb. " honey " jars. Upwards of ten stock cultures of *P. tectus* were maintained in order that the same number of larvae could be taken from each culture for each rearing experiment in order to ensure genetical constancy.

Foodstuffs. The foodstuffs employed in the rearing experiments were plain flour, wholemeal flour, rice flour (ground rice), and casein. Every effort was made to obtain these in as standardised a form as possible. The plain flour, wholemeal flour, and rice flour were purchased from a large firm of retailers, and through the courtesy of the latter I was put in touch with the millers. The plain flour contained proportions of Canadian, Plate, Russian and English wheats which were average at the time of purchase and suited the baking requirements of the Birmingham district. The wholemeal flour consisted of two-thirds No. 1 Manitobas and one-third English wheats (chiefly red), nothing having been extracted during the milling operations. The ground rice was ground from whole Patna rice with no added ingredients and milled in this country. The casein was a brand of industrial casein of South American origin and known to be liable to infestation by *P. tectus* and other beetles such as *Tribolium* spp. and *Dermestes vulpinus.* All the foodstuffs, before being used in the experiments, were sieved through copper gauze of 60 meshes to the inch.

Water Content of Foodstuffs.

This was determined for the four foodstuffs in equilibrium with a range of relative humidities, its importance having been pointed out by Sayed (8). The method of estimation of the water content was as follows :—Approximately fifty grammes of the foodstuff was placed in a culture cage (of the same type as used in the actual rearing experiments) and the latter placed within a humidity chamber. The temperature was thermostatically controlled at 27° C. for relative humidities of from 10% to 60%, and at 20° C. for relative humidities of from 70% to 90%. A period of two weeks was allowed for the foodstuff to get into equilibrium with the particular relative humidity given by the concentration of the potassium hydroxide solution. About ten grammes of the foodstuff were then weighed in a clean, dry petri dish, the foodstuff being scattered thinly over the bottom of the dish. The petri dish was then transferred to a steam oven for twenty-four hours and, after cooling in a desiccator, the dish was re-weighed and the loss in weight calculated as a percentage on the dry weight of the foodstuff.

The temperature of the petri dish during the twenty-four hours drying of the foodstuff varied between 96° C. and 98° C. The oven was of the type which allowed air currents, due to convection, to draw previously warmed dry air from the exterior and to allow the heated air to escape after passing over the contents of the dish. Consideration of the type of oven which allows of a very efficient movement of air brought about by means of a fan was dismissed as being impracticable in these experiments as, due to the light powdery nature of the foodstuffs used, loss not due to the water content would be bound to occur. A drying period of twenty-four hours in the oven was found to be sufficient in all cases to dispose of free water. More prolonged periods of drying showed small fluctuations in the weight of foodstuff which could not be attributed to loss of free water.

Preliminary experiments showed that two weeks was a sufficient length of time for the foodstuffs to get into equilibrium with the particular relative humidity. At relative humidities of 80% and 90%, however, apparent fluctuations in the amount of water absorbed during three and four weeks are probably due to fungal and bacterial action. The results obtained are tabulated (Table 1). It is seen from these results that, up to 60% relative humidity, casein contains appreciably less free water than wholemeal flour, plain flour, or ground rice. Apart from this, the foodstuffs contain very much the same amount of free water at any given relative humidity.

Apparatus. The culture cages and humidity jars used in the experiments together with a special sieve and mechanical sieving device have already been described (Hickin (9)).

Method of Infesting Foodstuffs.

Since sexual differences in the genitalia may be seen readily in the pupa, the first method of infestation tried was the isolation of pairs of sexed pupae. This involved the breaking open of the tough cocoons and the manipulation of the pupae for sexing. Although extreme care was used, it was found that many pupae died or produced adults which were crippled or delicate. On this account the method was discontinued.

The second method used was the isolation of virgin adults from unbroken cocoons. After emergence from the cocoons the virgin adults were left for one week isolated in the dark in order to mature. A few at a time were then

TABLE 1.

The amount of free water present in the experimental foodstuffs after two weeks in humidity chamber. Percentages calculated on the dry weight obtained after twenty-four hours heating in steam oven.

Tempera-ture, ° C.	Relative humidity	Percentage free water			
		Plain flour	Wholemeal flour	Casein	Rice flour
27	10	6·6	6·2	4·5	6·6
27	20	7·2	7·7	4·9	7·3
27	30	8·8	8·6	6·7	8·9
27	40	10·1	9·9	8·0	10·9
27	50	10·9	11·2	9·1	12·2
27	60	11·1	12·1	9·7	14·4
20	70	14·8	16·3	13·8	16·1
20	80	17·9	—	17·1	18·0
20	90	25·6	29·7	28·2	25·4

released together in a large dish and observed closely. Pairing took place quite readily both in daylight and in artificial (electric) light. With twenty-four beetles under observation for two hours an average of five pairings took place. Males quite readily try to effect coitus with other males. Copulation usually takes about five minutes. The male examines the female closely, tapping her head, thorax and abdomen rapidly with his antennae before mounting; the antennae of both male and female wave gently backwards and forwards during coitus. After copulation the pairs were segregated, each pair being placed in a culture cage containing foodstuff in equilibrium with a specified relative humidity. Although several of the pairs were observed to copulate more than once, no eggs were laid in any of the foodstuffs at any relative humidity. Most of the adults fell on to their backs in the soft food-stuff, and, unable to gain their feet, died in this position.

Attempts to infest the foodstuffs with eggs were unsuccessful. The eggs of this species are sticky, and particles of the foodstuff adhere. Small agglom-erates of foodstuff may be mistaken for eggs and, in addition, the eggs are very fragile and often break when the foodstuff is disturbed.

Finally, the method of infestation which proved successful was as follows. Groups of fully grown larvae at the stage just previous to cocoon-making were placed in the culture cages containing foodstuff in equilibrium with a range of relative humidities. In order to obtain a degree of genetical constancy throughout the experiments, not more than six larvae were the progeny of a single parent. This was accomplished by taking larvae from a number of separate and distinct stock cultures. The use of groups of fully fed larvae, besides not suffering from the disadvantages in manipulation as noted above, has several striking advantages. On account of the habit of the larvae of rolling up into a ball when disturbed, they can be transferred to the culture cage without any risk of damage if a camel-hair brush is used. Also, they spend a relatively long time resting before pupation and thus become inured to the environmental conditions before metamorphosis. Finally, as a group of adults hatch out at approximately the same time those running about over the surface of the foodstuff are of value to the others in helping them to regain their feet by running up to investigate the struggling ones.

When the adults, which emerged, died they were removed from the culture cage, softened by boiling in potash solution and the genitalia made out under the microscope.

RESULTS.

Tables 2 and 3 give the number and sex of the adults reared from larvae (Parent generation) in the four foodstuffs in equilibrium with various relative humidities. On no food were any adults produced at relative humidities of 10%, 20% or 30% (27° C.) or at 90% and 100% (20° C.). At the high humidities, the growth of moulds was an important factor. As the larvae were nearly full grown, it is probable that the nature of the food had little influence on the development. This is borne out by the examination of the separate figures, which have therefore been added together.

TABLE 2.

Adults emerging from sets of eighty larvae. (All foods added together.)

Temp.	R.H.	No. of adults			% developed
		♂	♀	Total	
27° C.	40%	3	2	5	6
27° C.	50%	19	18	37	46
27° C.	60%	33	38	71	89
20° C.	60%	13	23	36	45
20° C.	70%	24	24	48	60
20° C.	80%	40	28	68	85
	Totals	132	133	265	55·2

TABLE 3.

Data of Table 2 grouped according to foodstuff.

Foodstuff			No. of adults			% developed
			♂	♀	Total	
Wholemeal	.	.	43	40	83	69
Plain flour	.	.	28	29	57	47·5
Casein	.	.	34	29	63	52·5
Rice flour	.	.	27	35	62	52
Totals	.	.	132	133	265	55·2

The animals whose emergence is put on record in Tables 2 and 3 were left on food and allowed to breed. The numbers emerging in this generation are shown in Table 4. Besides giving the actual numbers emerging, a figure is given for offspring per ♀ parent; as can be seen from Table 2, the number of female parents differed widely in the various cultures.

TABLE 4.

Temp. R.H.	27° C. 50%			27° C. 60%			20° C. 60%			20° C. 70%			20° C. 80%			Totals		
	♂	♀	no. per ♀	♂	♀	no. per ♀	♂	♀	no. per ♀	♂	♀	no per ♀	♂	♀	no. per ♀	♂	♀	no. per ♀
Wholemeal. Plain	3	4	1·0	16	7	2 3	9	11	1·22	19	15	4 25	22	31	12 6	79	68	3 7
flour .	1	0	0 25	9	4	1 3	0	1	0 025	7	4	2 2	22	11	6 6	39	20	2·0
Casein .	0	0	—	1	3	0 4	0	0	—	3	1	1 3	8	6	1 6	12	10	0·3
Rice flour .	0	0	—	0	0	—	0	0	—	19	22	5·1	43	39	9 1	62	61	3·5
Totals .	4	4	0·4	26	14	1·1	9	12	0 9	48	42	3 75	105	87	6 6	192	159	1·32

Duration of life-cycle.

It was not found practicable to study the duration of a number of individual life-cycles. An indication of the average duration was, however, obtained by finding the difference between the average dates of emergence of parents and offspring (animals recorded in Tables 2 and 4, respectively). These average figures are recorded in Table 5.

TABLE 5.

Temperature R.H.	Average duration of life-cycle in weeks				
	27° C. 50%	27° C. 60%	20° C. 60%	20° C. 70%	20° C. 80%
Wholemeal . . .	16·0	10·5	19·0	21·5	21·0
Plain flour . . .	11·0	—	—	24·0	28·5
Casein . . .	—	16·0	—	29 5	36·0
Rice flour . . .	—	—	--	24·0	25·0
Average . . .	15·4	10·7	19·0	23·3	25·1

1. From the table it may be seen that the shortest average length of life-cycle was 10·5 weeks, which occurred in wholemeal flour in equilibrium with 60% relative humidity at 27° C.

2. The longest average length of life-cycle was 36 weeks, which occurred in casein in equilibrium with a relative humidity of 80% at 20° C.

3. In wholemeal flour, plain flour, and casein the average length of life-cycle was approximately twice as long at 20° C. as it was at 27° C.

4. In plain flour and casein an increase in relative humidity from 70% to 80% at 20° C. increased the average length of the life-cycle. In wholemeal flour the average length of the life-cycle was approximately the same at 70% relative humidity as at 80%.

Length of Life of Pupa at Different Relative Humidities.

In view of the risk of damage to the pupa when a cocoon is opened, use was made of the habit of the larva of utilising the glass sides of the culture cage as one side of the cocoon. In this way the changes from larva to pupa, and from pupa to adult, were observed without disturbing the cocoons. Accordingly groups of approximately 50 larvae were placed in culture cages with plain flour in a humidity chamber of relative humidity 50%. When the larvae had finished making cocoons the contents of the culture cages were tipped out with the exception of cocoons whose contents were visible through

F 2

the glass. These cocoons were then numbered on the glass with black indelible ink. The culture cages containing the marked cocoons were placed at different relative humidities and were examined at a fixed time daily. The length of the pupal stage and the length of the adult resting stage before emergence was determined. Table 6 shows the average length of pupal stage and average length of adult resting stage for the range of relative humidity.

TABLE 6.

Length of pupal stage and maturation of adult with varying relative humidity.

Relative humidity, %.	Average length of pupal stage, days	Average length of maturation of adult, days	Average time in cocoon from metamorphosis into pupa	Temp., ° C.
10	All larvae died in cocoons			27
30	All larvae died in cocoons			27
40	12·7	8·3	21·0	27
50	11·3	9·7	21·0	27
60	11·0	7·25	18·25	27
70	13·8	9·5	23·3	20
80	16·1	7·4	23·5	20
90	13·4	10·0	23·4	20

Influence of free water on length of life and reproduction of adults.

Groups of 50 adults which had emerged in the previous 14 days, and had been feeding on wholemeal flour, were isolated into two series. In one, small aluminium tubes $\frac{1}{4}'' \times 1''$ filled with wet cotton wool were placed in the culture cages, one in each. In the other, there were no tubes of wet cotton wool. The insects were given no food. The cages were then placed in pairs in the humidity chambers and each week the dead were removed and sexed. The humidity control was only approximate because of the wet cotton wool. Table 7 gives the mean survival period of these insects. A number of adults was often to be seen drinking, with mandibles plunged into the wet cotton wool. It may be noted that in all the cages, even those without water, some eggs or larvae were found during the experiment, so the insects may lay even in the absence of foodstuffs.

TABLE 7.

Mean survival period of beetles with and without water (weeks).

Temp. R.H.	27° C. 10%		27° C. 30%		27° C. 60%		20° C. 80%		20° C. 90%	
	+w	−w	+w	−w	+w	−w	+w	−w	+w	−w
♂	5·3	2·8	6·2	3·8	4·0	3·6	13·4	3·0	5·8	7·1
♀	5·9	2·7	7·2	3·7	3·7	4·2	16·0	4·0	8·0	8·4

It may be concluded that without water to drink *P. tectus* survives about three weeks except at very high humidities (90%), when they survive longer. When given water to drink the survival period seems to depend only on temperature and not on relative humidity, but the figures do not allow of any very definite conclusions.

Some experiments were also made to show the effect of free water on the rate of reproduction. Groups of 30 adults which had emerged in the previous

14 days were put in cages with wholemeal and plain flour in equilibrium with various relative humidities at 20° C. A tube of wet cotton wool was put in each cage (placed so that the wool did not touch the flour). Larvae were sieved out of the flour from time to time and the number obtained during 8 months is recorded in Table 8. The high number of offspring may be compared with the low numbers recorded in Table 4 (female without access to free water).

TABLE 8.

R.H.	Food	No. of larvae
40%	Wholemeal	394
50%	Plain flour	265
50%	Wholemeal	909
60%	Plain flour	335
60%	Wholemeal	678

Effect of adding yeast or wheat germ to the foodstuffs.

In the first set of experiments, 5% of yeast powder (by volume) was added to plain flour and casein respectively, and well mixed. Cultures to which yeast had not been added were kept as controls. One set of 4 cultures was kept in equilibrium with 60% R.H. at 27° C., another in equilibrium with 80% R.H. at 20° C. Ten fully fed larvae of *P. tectus* were introduced into each culture and the adults to which these gave rise were allowed to breed and produce a second generation. The results of these experiments are summarised in Table 9.

TABLE 9.

Experiments with added yeast powder. Emergence of generation (see Table 1) with average length of life-cycle.

Relative humidity 60% 27° C.	No. of males	No. of females	Total no. of adults	No. per parent female	Average length of life-cycle
Plain flour	1	4	5	1·2	14 wks.
Plain flour with yeast powder .	6	1	7	7	10·5
Casein	2	2	4	2	12
Casein with yeast powder . .	29	18	47	9·4	8
Relative humidity 80% 20° C.					
Plain flour	6	3	9	2·2	25
Plain flour with yeast powder .	24	19	43	10·8	20
Casein	5	6	11	2·8	38
Casein with yeast powder . .	24	18	42	14·0	21

The importance of an addition of yeast to either plain flour or casein is clearly shown both in the increase of offspring per female and in the shortening of the life-cycle. In the experiments with casein and yeast a higher number of offspring per female (at 20° C. 80% R.H.) and a shorter life-cycle (at 20° C. 60% R.H.) were recorded than in any other set of conditions tested.

In a second set of experiments 5% yeast powder by volume was added to pure potato starch and pure casein, one being almost pure carbohydrate, the other pure phosphoprotein. A third mixture was made by adding to potato starch 5% by volume of a substance consisting mainly of wheat germ.

Cages containing pure potato starch and casein, respectively, were kept as controls and the experiment was carried out in duplicate. When the food-stuffs were in equilibrium with 70% R.H. at 20° C., twenty first-stage larvae were introduced into each cage. In Table 10 the average duration of life-cycle and the numbers completing their development are recorded. The effects of the addition of yeast (or wheat germ) to the pure foods is again evident. The few individuals which completed their development in pure potato starch apparently did so by eating the dead bodies of other larvae, for only the head capsules could be sieved out, whereas in casein whole larval skins were obtained.

TABLE 10.

Foodstuffs in equilibrium with 70% relative humidity 20° C. Emergence of adults from infestation with 20 first-instar larvae.

Foodstuff		Number emerged			Average length of time from infesta-tion to emergence in weeks
		Males	Females	Total	
Potato starch	1	0	1	1	16
	2	2	0	2	16
Potato starch with yeast powder	1	6	11	17	12
	2	9	5	14	13
Potato starch with wheat germ	1	9	4	13	13
	2	6	9	15	14
Pure casein	1	4	—	4	20
	2	1	1	2	37
Pure casein with yeast powder	1	12	6	18	14
	2	8	9	17	14

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SOME OBSERVATIONS ON *MONONYX NEPAEFORMIS* (FABRICIUS 1775), A TOAD-BUG (MONONYCHIDAE, HEMIPT.-HETEROPT.)

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MEMBERS of this little-known family of the Cryptocerata (also called GELASTO-CORIDAE, NERTHRIDAE, or GALGULIDAE) are for the most part tropical or subtropical in distribution. They occur in North, Central and South America, from the United States to the Argentine, in the West Indies, in Australia (New South Wales and Queensland), in the Malay Archipelago (New Guinea, Sumatra), China (Mou-Pin), and also in India.

Apart from the description of the life-history of *Gelastocoris oculatus* Fabricius in the United States by Hungerford (1922 : 145–171), there is practically no published information concerning the ecology of any of the species—though their raptorial front legs indicate that they are all predacious.

Up to the present, the family has been generally regarded as semi-aquatic, frequenting the borders of ponds and streams (Imms, 1938 : 370). Some species occur in stagnant water, and some in fresh (Champion, 1901 : viii), and they frequently have an earthy incrustation which is hard to remove (Champion, 1901 : 350). *Mononyx nepaeformis* in Trinidad, however, does not have such habits, and its habitat would appear similar to that of *M. bipunctatus* Melin taken in Peru (Melin, 1930 : 194).

M. nepaeformis has been taken commonly, both by the writer, and by Dr. H. B. N. Hynes, in a small banana plantation attached to the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, during both the wet and dry seasons of 1941–42. There is neither standing nor running water anywhere in the vicinity of this plantation, and, in the dry season, the ground becomes parched and dry. The insects are most readily found under débris, such as heaps of dry grass or old pawpaw stumps, and seem to spend much of their time burrowing in the soil, where they are common also, though less easily detected, while nymphal exuviae have often been found underground. In the laboratory, too, they will readily burrow in moderately loose soil.

All their time, however, is not spent in this manner, for the writer has swept the species off low vegetation on to which it had climbed, presumably in search of prey.

The food of *M. nepaeformis* consists of small, preferably soft-bodied, insects of various kinds suited to its size of about 7 mm. long. In the laboratory, termites were the most readily accepted and the most hungrily devoured, while small moths and beetles were not received with favour, presumably because of the scales of the former and the hardness of the latter.

In the field, the natural food was not determined, but termites may feature largely in the diet, and probably also a soil-dwelling earwig (*Euborella* sp.) with which *M. nepaeformis* has on several occasions been found associated, and which is readily taken as food in the laboratory.

M. nepaeformis, when disturbed, will at once feign death by drawing all its legs close to the body, and will remain in that position for several minutes, even when put on its back.   Its normal mode of progression is by a series of jerky runs, and it can jump several times its own length with ease.   When catching its prey, it stays perfectly still until an opportune moment arrives, and then pounces on its victim, holding it firmly between its strong raptorial front legs. It then inserts its proboscis and sucks the prey dry.

Attempts were made to breed the species in captivity, and mating was observed.   The process is for the male to jump on to the back of the female, and to incline himself slightly to the right (*i.e.* abdomen to the left, as observed by Hungerford (1922 : 147) in relation to *G. oculatus*).   Unfortunately no eggs were obtained, but last-instar nymphs have been reared through to adults in soil, and the duration of this stadium was found to be at least two weeks. Eggs were not found in the field, but it seems probable that oviposition is similar to that indicated by Hungerford (1922 : 148) for *G. oculatus.*

A single specimen of *M. nepaeformis* was found dead with a fungus (probably *Cordyceps* sp.) growing out of the pronotum.

Thanks are due to Mr. H. G. Barber, of the United States Department of Agriculture Bureau of Entomology and Plant Quarantine, for determining this species, and also *Mononyx montandoni* Melin, which was described from Venezuela (Melin, 1930 : 191).

A male and a female of this latter species, which is about half the size of *M. nepaeformis,* were taken by the writer on the wet mud of a rice seed-bed at St. Augustine, Trinidad, 19.xi.1941.

Three species are thus known from Trinidad, namely, *M. nepaeformis* and *M. montandoni,* already mentioned in the paper; and *M. bipunctatus* Melin. The latter record is based on a specimen in the Museum at Copenhagen (Melin, 1930 : 177).

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A GYNANDROMORPH OF *AËDES AEGYPTI* L. (*STEGOMYIA FASCIATA*), DIPTERA

By W. J. P. SMYLY, B.Sc.

THE occurrence of gynandromorphs amongst mosquitos appears to be comparatively rare. In Britain, only eight cases have been recorded during the past twenty years, the latest case of gynandromorphism having quite recently been reported by Classey from the Army School of Hygiene, Mytchett, Hants. Classey describes the most unusual occurrence of an apparently normal female of *Theobaldia annulata* Schrank possessing a typical male hypopygium. Of the remainder, three cases were provided by Edwards (1917); one by Shute (1926), and three by Marshall from the British Mosquito Control Institute, Hayling Island. Four of the eight were the same species, namely *Aëdes punctor*; and of these, three were caught by Edwards within a period of ten minutes on Harrow Weald Common, Middlesex, and the fourth was provided by Shute. Those recorded by Marshall were *Aëdes detritus, Culex pipiens* and *Culex molestus*.
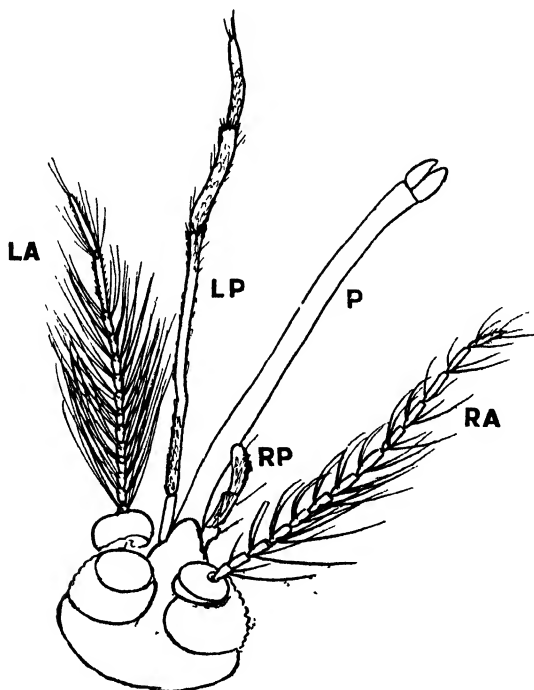
FIG. 1.—Head of a gynandromorph *Aëdes aegypti*. LA, left antenna; LP, left palp; P, proboscis; RP, right palp; RA, right antenna.

The specimen described below was discovered in a stock of *Aëdes aegypti* which has been reared in the London School of Hygiene and Tropical Medicine for a considerable number of years. During an experiment with caged mosquitoes,

to test the effectiveness of a repellent substance smeared on the arm, a mosquito was observed, apparently a male, endeavouring to pierce the skin. At each attempt, however, its proboscis only bent, and on being removed from the cage for closer examination, its peculiar nature was observed.

Description of specimen (fig. 1):—Left antenna, as in male, normal. Right antenna, as in female, normal. Left palp, as long as normal male, but not so hairy. Right palp, as in female, basal joint somewhat enlarged. Hypopharynx, as in female, normal. Right maxilla and mandible, as in female; left maxilla, half the length of normal female, and left mandible missing. Left front claw, as in male, normal; right front claw as in female, normal. External genitalia, male, normal.

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THE HARVESTING OF ALDER BUCKTHORN (*RHAMNUS FRANGULA*) AND THE EFFECT ON THE INSECT FAUNA

By G. Fox-Wilson, N.D.H., F.R.E.S.

An opportunity of studying the effect of the temporary disappearance of an essential food-plant upon two insect species has arisen in recent months owing to the extensive cutting to ground-level of the Alder Buckthorn (*Rhamnus Frangula*) on commons in the southern and south-eastern counties of England and possibly elsewhere.

This widespread harvesting of Buckthorn arises from the necessity to ensure supplies of home-grown stocks for the Ministry of Supply. The value of the plant lies in the cathartic properties of the bark and the superiority of its wood in the preparation of charcoal.

The insects concerned are the Brimstone butterfly, *Gonepteryx rhamni* L., which is a monophagous species; and the Aphid, *Aphis rhamni* Boyer (*A. abbreviata* Patch),[1] which displays monophagy during the winter phases of its life-cycle.

Lepidopterists may be able to elucidate the problem as to the effect on Brimstone populations of widespread harvesting of Buckthorn, for it is understood that large areas were denuded of this shrub during the last war (1914–1918).

The value of the butterfly is aesthetic : and as a harbinger of spring its absence would be lamentable. The applied entomologist is, however, specially concerned with the importance of the Aphid as a Potato pest and to the fact that this species has been recorded as a vector of Solanum Virus 3 in the United States,[2] though it has so far not been proved to transmit the disease in this country.

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THE PROBABLE MECHANISM OF PHASE VARIATION IN THE PRONOTUM OF LOCUSTS

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Introduction.

One of the recognised morphological differences between adults of the solitary and gregarious phases of locusts is in the shape of the pronotum. The difference is particularly striking in *Locusta migratoria* (L.) and is best observed in the profile view, ph. *solitaria* having a definitely convex median carina which, in the ph. *gregaria*, is straight, or even slightly concave (fig. 1). Duarte (1939) has shown experimentally that the degree of convexity of the carina remains unchanged in the solitary phase from the second hopper instar to the adult, and very little difference is observed between the phases in the first three instars, but in the 4th instar the carina in the gregarious phase is perceptibly less convex, and in the 5th it becomes straight in profile. Parallel with the depression of the carina, the pronotum of the ph. *gregaria* becomes distinctly constricted in the middle but broadened in the shoulders, and its metazona becomes relatively shorter and more rounded behind, instead of being angular as in ph. *solitaria*. Since it is known now that the differentiation of the gregarious phase is mainly (and probably even entirely) due to the greater activity in the hopper stage (Faure 1932; Husain and Mathur 1936; Uvarov 1937), the question arises as to the probable connection between activity and the pronotal shape.

Maloeuf (1935) has shown that the configuration of the insect exoskeleton appears to be influenced by the pull of the muscles attached to it, when they contract. If this is the case, then a greater deformation should be expected in a more active phase of the locust, and the morphological changes in the pronotum of the ph. *gregaria* should correspond with the arrangement and the attachment of the thoracic muscles. Moreover, a study of the muscles likely to produce the changes in the pronotum should suggest which kinds of movement may be of particular interest as probable factors of its deformation.

The problem may be attacked from two sides, viz. (1) the anatomical, by a study of the thoracic musculature in relation to the pronotal shape, and (2) the physiological, by a study of the types of movement prevalent in the ph. *gregaria* as compared with ph. *solitaria*. Only the anatomical method can be applied at present, because of the lack of facilities for work with live locusts, and the results are published in the hope of attracting the attention of more fortunately placed investigators.

Skeleton of the Prothorax.

Before the muscles can be described a brief account of the prothoracic skeleton must be given. Both the skeleton and the muscles of this region in *Locusta* agree closely with those of *Dissosteira carolina* L., described by Snodgrass (1929), and the nomenclature used by him will be retained in the following discussion.

The prothorax is attached to the head by a neck membrane (figs. 2, 3, 4, NM), in which are situated two pairs of cervical sclerites (CS 1, CS 2); it is attached to the mesothorax by an intersegmental membrane (IM). The greater part of the prothorax is covered by the arched pronotum. The edges of the pronotum

are reflected back, both folds being free from the outer wall for a short distance in the dorsal region, but for the rest of their length they are fused with it. The neck and the intersegmental membranes are attached to the true edges of the prothorax, the neck membrane in front of ridge *a* and the intersegmental membrane a little way behind ridge *e* (fig. 2). The pronotum therefore projects slightly over the head in front and to a considerable extent over the mesothorax behind, when the animal is at rest. The extent of the folds is not visible from the outside.
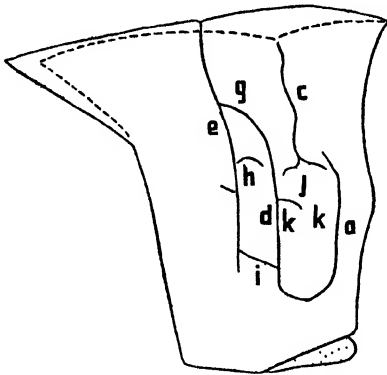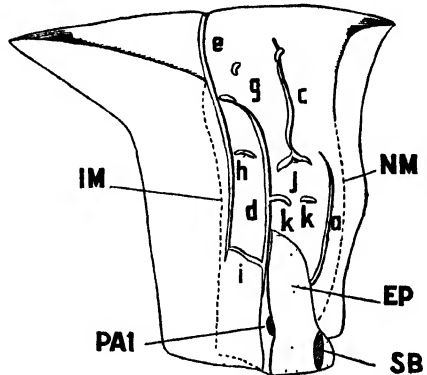
FIGS. 1–2.—1. Outside view of the right side of pronotum of the ph. *solitaria* (dotted line showing dorsal profile of the ph. *gregaria*). 2. Inside view of the left side of pronotum of the ph. *solitaria*.—EP, episternum; IM, intersegmental membrane; NM, neck membrane; PA, pleural arm; SB, skeletal bridge; *a–k*, grooves on the outside and corresponding ridges on the inside.

Various grooves seen on the outer surface of the pronotum (fig. 1) correspond with internal ridges (fig. 2) and it is on, or below, some of these that many of the muscles are inserted. There are four main vertical ridges, *a, c, d, e* (*d,* curving posteriorly at its dorsal end to meet *e*); and several horizontal or oblique ones, *g, h, i, j, k,* of which some meet the vertical ones.

The pleura appear externally only as small projections at the base of the pronotum (fig. 1). Internally, however, they can be seen as two plates, the episterna (fig. 2, EP), lying against the lower part of the pronotum immediately in front of the ridge *d.* At its posterior end each plate turns inwards and ends in two projections—a dorsal one, the pleural arm (PA 1) and a ventral one which articulates with the coxa.

The ventral skeleton of the prothorax is formed by the sternum. This consists of two plates, an anterior one bearing two lateral processes, the sternal arms (fig. 4, SA 1), each of which joins with the corresponding pleural arm (PA 1), and a posterior one, which has a median groove externally, corresponding with an internal projection, the spina (SP 1). Anteriorly the sternum is joined with each episternum by a skeletal bridge (fig. 2, SB).

MUSCLES OF THE PROTHORAX.

An account of the musculature of *Locusta* has been given by Maki (1938), but his treatment is brief and his figures purely diagrammatic so that the paper is of little value for our purpose.

The muscles of the prothorax fall into four groups :—

1. *Muscles Moving the Head Directly.*

There are five main pairs of muscles in this group—three towards the dorsal side, one ventral and one ventro-lateral pair. The three dorsal pairs are the 1st and 2nd protergals of the head (fig. 3, 1 *pth*, 2 *pth*), both arising from the dorsal part of the pronotum and running somewhat obliquely downwards, and the dorsal longitudinal pair (*dl*) arising from the 1st thoracic phragma : these are all inserted on the post-occipital ridge of the head. The 1st ventral longitudinal muscle of each side (1 *vl*), arising from the sternal arm, goes to the base of the head. The ventral lateral neck muscle (not shown in the figures) arises from the anterior edge of the episternum and goes to the neck membrane. The head will be raised by the simultaneous contraction of the dorsal muscles and lowered by the contraction of the ventral pairs.

Increased contraction of the protergals would tend to shorten the metazona, for although they are not inserted on the metazona, their effect would be transmitted to this region; as they are situated somewhat obliquely, it would also tend to depress the dorsal carina. The dorsal longitudinal muscles might also have some effect in shortening the metazona, but since the pull would have to be transmitted through the thin intersegmental membrane, their effect would be slight. The ventral lateral muscles, which help in turning the head, would probably have no effect on the changes under consideration. The effect of the 1st ventral longitudinal muscles will be considered later in connection with the 3rd and 4th ventral longitudinals.

2. *Muscles Moving the Cervical Sclerites.*

The cervical sclerites (figs. 3, 4, CS) are moved by five pairs of muscles. Two pairs of cephalic muscles (not shown in the figures) arise from the post-occipital ridge and pass obliquely down and back, each going to one pair of sclerites. Two pairs of protergal muscles (fig. 3, *ptc*) arise from the pronotum below ridge *j* and go to the 1st cervical sclerite. The combined action of cephalic and protergal muscles will, by pulling each pair of cervical sclerites into a straighter line, result in pushing the head forward (Snodgrass 1929). The prosternal muscles (fig. 4, *psc*) pass from the sternal arm of one side to the 1st cervical sclerite of the opposite side; they may help in lateral movement of the head.

The protergal muscles of the cervical sclerites might, by increased contraction, help to bring about a depression of the dorsal carina, and the prosternals, by pulling on the prosternal arms, would probably help to increase the constriction of the pronotum. The cephalic muscles can have no effect on the shape of the pronotum.

3. *Muscles Moving the Prothorax in Relation to the Mesothorax.*

The pair of broad tergo-pleural intersegmental muscles (fig. 3, *tpi*) lie somewhat dorsally and extend from the intersegmental membrane to the posterior side of the dorsal part of the ridge *c*. The paired sterno-pleural intersegmental muscles (figs. 3, 4, *spi*) run obliquely from the prosternal arms to the sides of the mesothorax. The three remaining pairs are more ventrally placed : the 2nd ventral longitudinal muscles (2 *vl*) run between the prosternal and the mesosternal arms, and the 3rd and 4th ventral longitudinal pairs (3 *vl*, 4 *vl*) are attached to the 1st spina, the 3rd ending on the mesosternal arm, and the 4th on the 2nd spina.

The tergo-pleural and the sterno-pleural intersegmental muscles will, on simultaneous contraction, pull the prothorax back. The three ventral pairs, if they contract alone, will tilt it down, but in conjunction with the two former pairs will pull the whole prothorax back.

If the tergo-pleural intersegmental muscles are used more often they will help to depress the carina. The 2nd ventral longitudinal muscles together with the 1st ventral longitudinals (described above) would, if they contracted together, increase the constriction of the pronotum by pulling on the prosternal arm,
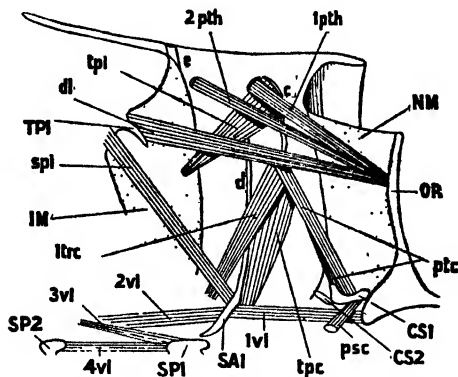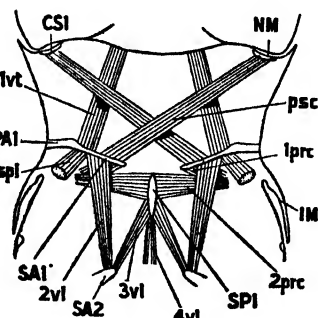
FIGS. 3–4.—3. Inside view of the left side of pronotum of ph. *gregaria* showing some of the muscles. 4. Dorsal view of some of the more ventral muscles of the prothorax and mesothorax in ph. *gregaria*.—CS, cervical sclerite; *dl*, dorsal longitudinal muscle; IM, intersegmental membrane; NM, neck membrane; OR, occipital ridge; PA, pleural arm; *ptc*, protergal muscle of cervical sclerite; *prc*, posterior rotator of coxa; *psc*, prosternal muscle of 1st cervical sclerite; *pth*, protergal muscle of head; SA, sternal arm; SP, spina; *spi*, sternopleural intersegmental muscle; TP, thoracic phragma; *tpc*, tergal promotor of coxa; *tpi*, tergo-pleural intersegmental muscle; *trc*, tergal remotor of coxa; *vl*, ventral longitudinal muscle.

since they both pass obliquely inwards from this, the 1st going anteriorly and the 2nd posteriorly. The sterno-pleural muscles will, however, tend to counteract this, as they run dorsally and outwards from the sternal arm. The 3rd and 4th ventral longitudinals do not seem to affect the changes in shape of pronotum.

4. *Muscles Moving the First Pair of Legs.*

The only leg muscles that need be considered are those arising from the prothorax. These are the muscles moving the coxa and three branches of a large muscle moving the trochanter. The tergal promotor of the coxa (fig. 3, *tpc*), which pulls the leg forward, is inserted on the trochantin, a small skeletal plate lying just in front of the coxa, and has two branches in *Locusta*, though only one in *Dissosteira*. The inner branch arises a little below ridge *j*, and the outer below ridges *k k*.

There are three tergal remotors, all inserted on the posterior edge of the coxa. The 1st (fig. 3, 1 *trc*) arises below ridge *j*, the 2nd below ridge *i* and the 3rd, a narrow muscle, arises more dorsally below ridge *h*. Extra contraction of the promotors or remotors will help to depress the carina, since they are all inserted on the pronotum below that part of the carina which is most raised in the phase *solitaria*.

The two pairs of posterior rotators of coxa, of which the 1st (fig. 4, 1 *prc*)

arises on the sternal arm and the 2nd (2 *prc*) on the 1st spina, are also inserted on the posterior edge of the coxa. These seem to play no part in the observed phase changes.

The abductors of the coxa (not shown in the figures) are a pair of broad muscles each arising on the episternum and the anterior face of the pleural arm (in *Dissosteira* they arise from the episternum only). Each narrows to its insertion on the outer side of the coxa. The opposing muscle pair, the adductors of the coxa (not figured), pass from near the posterior side of the junction of the sternal and pleural arms to the inner edge of the coxa. The adductors, being inserted on the inner edge of the coxa, will tend to pull the pleural arms, and, therefore, the pronotum, inwards and thus to deepen the constriction. The abductors, being inserted on the outer edge, will have no such effect.

The depressor of the trochanter (not figured) has two of its branches arising from the coxa and three from the prothorax. Of the latter group, a large branch arises below ridge *h*, another fairly large one arises on the episternum and passes over the abductor of the coxa, and a third smaller one arises from the underside of the pleural arm. They are all inserted on a projection from the trochanter into the coxa. The first of these branches, arising somewhat dorsally, would, on increased contraction, help to lower the carina, and contraction of the second branch might have some effect on deepening the constriction.

MOVEMENTS LIKELY TO AFFECT PRONOTAL SHAPE.

The above discussion of the probable mechanical effects of the contraction of individual muscles on the development of the ph. *gregaria* characters may be summarised as follows :—

(A) *Lowering of pronotal carina* is induced by the action of (1) 1st and 2nd protergal muscles when the head is raised, or pulled back; (2) protergal muscles of cervical sclerites when the head is pushed forward; (3) tergo-pleural intersegmental muscles when the prothorax is pulled back; (4) promotors of the 1st legs; (5) remotors of 1st legs and (6) 1st branch of depressor of trochanter of 1st leg, which all take part in movements of the 1st leg.

(B) *Constriction of pronotum* is affected by the action of (1) prosternal muscles of the 1st cervical sclerites moving the head with regard to the prothorax; (2) 1st and 2nd ventral longitudinal muscles when the head and prothorax are moved down, or back; (3) possibly also the 2nd branch of the depressor of the trochanter involved in movement of the 1st leg.

(C) *Shortening of metazona* is affected by the action of protergal muscles which raise, or pull back, the head (and possibly also of the longitudinal dorsal muscles taking part in the same action).

It will be seen that the muscular contractions likely to be concerned in the variation of pronotal shape towards ph. *gregaria* are mainly those responsible for movements of the head and prothorax in relation to the body, and of the first pair of legs. Leg movements are obviously concerned with crawling, and a greater intensity of wandering, which is characteristic of the behaviour of ph. *gregaria*, would thus inevitably contribute to the morphological change. As regards movements of the head, which appear to play an even more important part, it might be suggested that a gregarious hopper passes relatively more time in wandering over the horizontal surface of the ground, where it requires more muscular exertion to support the head in position, than is needed for a solitary hopper sitting vertically on a plant, with the head resting on the thorax by the force of gravity; it must be remembered that the head of a hopper is very large in relation to the thorax and probably very heavy, being strongly chitinised.

This suggestion finds supporting evidence in the fact that most ground-living (geophilous) ACRIDIDAE are characterised by a depressed and constricted pronotum, while a high and non-constricted shape is typical of plant-climbing (phytophilous) species. It may also be argued that a gregarious hopper would obtain more exercise of the muscles moving the head in connection with its feeding, which should be more intensive owing to the greater intensity of its metabolism as compared with ph. *solitaria*.

In general, the modification of the pronotal skeleton by the action of muscles supporting and moving the head of a locust hopper is but one of the numberless illustrations of the principle that the " skeletal form brought about by growth is to a very large extent determined by mechanical considerations " (Thompson 1917 : 712). An analogous case amongst vertebrates is found in rhinoceroses, the grazing species of which differ from those feeding on tree branches by the greater development of the occipital crest, induced by the pull of the muscles supporting the head. The difference can even be produced in an individual, since a tree-feeding rhinoceros kept long in captivity and forced to feed from the ground may develop an abnormal occipital crest (Zeuner 1934). The fact that in a locust the muscular strain causes a depression of the pronotal carina and in a rhinoceros a greater development of the occipital crest, depends, of course, on the skeleton being external in the first case and internal in the second. The visible results are diametrically opposed, but the principle remains.

Thus, the phenomenon of individual phase change in the locust pronotum may be regarded as a striking example of a morphological response of a growing organism to a modification of behaviour caused by environmental factors. Seen in this light, the pronotal phase characters cease to be mere biometric deductions and receive a reasonable biological explanation. Further confirmation of this idea can be obtained through studies on the types of movements particularly characteristic of the ph. *gregaria* and ph. *solitaria*, respectively, and the present paper suggests that in such studies attention should be concentrated particularly on the movements of the head and of the first pair of legs. The above, of course, refers to the pronotal shape only ; the development of other phase characters may be due to other causes.

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LARVAE OF THE BRITISH TRICHOPTERA. 5

By N. E. Hickin, Ph.D, F.R.E.S.

Odontocerum albicorne Scopoli (Odontoceridae).
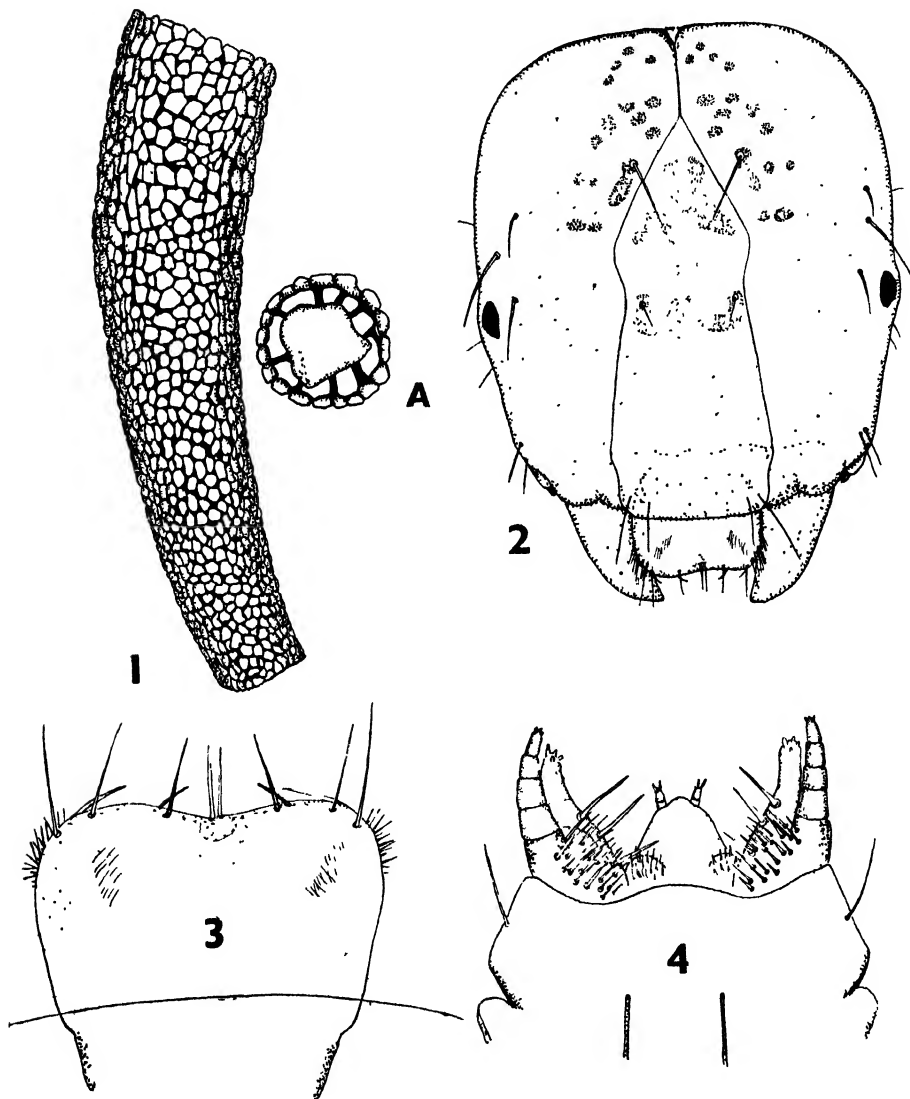
FIGS. 1–4.—*O. albicorne.* 1, larval case; a, view of posterior end of larval case; 2, head of larva; 3, labrum of larva; 4, maxillae and labium.

THE larva of this species inhabits swiftly-running streams with a rocky bottom, the specimens described below having been obtained from Dowles Brook, Bewdley, Worcestershire, a brook which, although practically at sea-level, has many characters of a subalpine stream. It is swiftly running over a rocky bed and there is no phanerogamic vegetation present. The water is cold even in summer, being shaded by dense woodland for many miles of its length.

Odontocerum albicorne is the sole British representative of the family ODONTOCERIDAE.
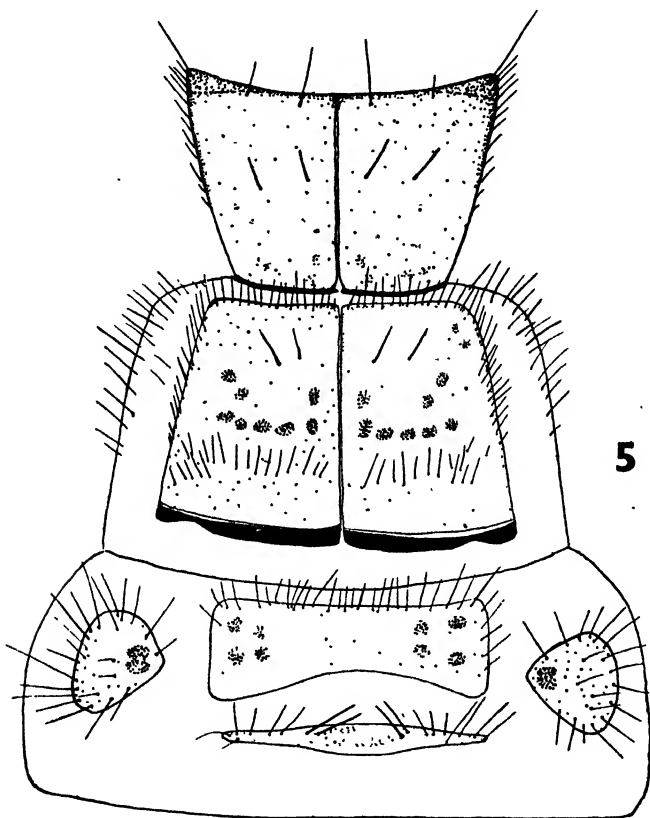
FIG. 5.—*O. albicorne.* Thorax of larva.

Case. The larval case is composed of a single layer of large grains of sand, the exterior having a fairly smooth texture. It is slightly curved and tapers towards the posterior end. One or several pebbles incompletely block the tail end, held in position by a web of dark brown secretion, and before pupation the head end is blocked also by a small pebble. Size : up to 20 mm. in length and 4 mm. in breadth at the larger end. *Larva* : the eruciform larva is cylindrical and is widest at the thorax. The sclerotised parts are light chestnut brown in colour whilst the abdomen is greyish-white. Size : up to 18 mm. in length and 3 mm. in breadth. *Head :* hypognathous, ovoid in shape with oral end slightly attenuate, light chestnut brown with outer edge of mandibles black. Clypeus elongate

with two slight concavities along each lateral margin, one smaller near the oral end and the larger, near the middle. At the aboral end of the clypeus is an anchor-shaped mark with the " eye " divided. A spine is borne at both oral apices of the mark whilst a light coloured spot is situated at each of the remaining four apices. Several groups of dark spots are situated on the frons near the aboral end of the clypeus and near the median frontal suture.
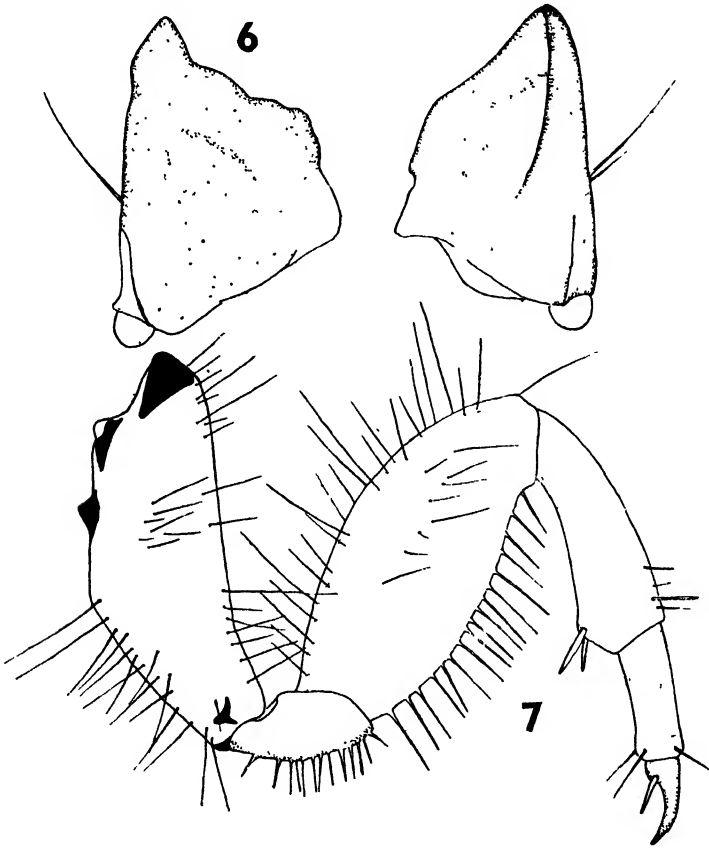
FIGS. 6–7.—*O. albicorne.* 6, mandibles of larva; 7, prothoracic leg of larva.

A spine projects from a single larger spot lying on each side of the aboral end of the clypeus. A group of three or four spines lies near each eye. *Mouth-parts :* labrum with anterior margin concave and small median sclerotised depression. Four pairs of bristles and two pairs of inwardly bent spines along anterior margin. *Mandibles :* wedged-shaped obtuse and slightly asymmetrical. Outer margin folded and heavily sclerotised. A few blunt teeth on the cutting edge more defined on the left than on the right. A group of bristles on the outer edge. *Maxillae :* maxillary lobe conical with three curved inwardly projecting spines lying along the inner edge. Many smaller spines at base of lobe. Maxillary palp four-segmented with insertion into lobe sclerotised, giving appearance of another segment. (Ulmer gives five segments, Rousseau four.) Labium conical, labial palps two-segmented. Two hairy lobes at base of labium. *Thorax :* pronotum sclerotised, concave

anteriorly for insertion of head. Hairy and darker in colour at the sides. Sclerotised portion of mesonotum consists of two large plates reaching laterally almost as far as pleural region. Posterior margin black. A few dark spots run transversely at about the middle, and just posterior to these is a transverse row of hairs. Anterior and outer margins of sclerotised plates hairy. Metanotum has four sclerotised patches. Two are transverse, lying one behind the other. The anterior patch is large, with its posterior margin deeply
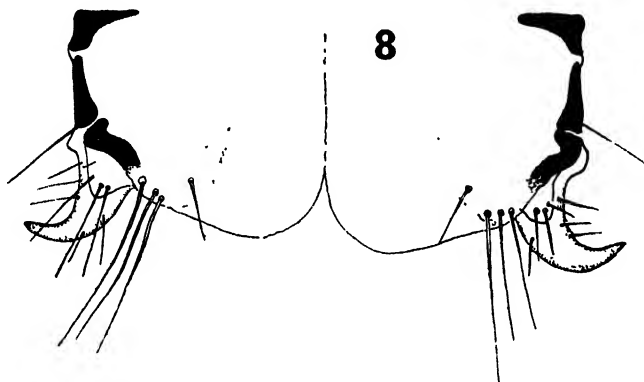
FIG. 8.—*O. albicorne.* Anal claws of larva.

concave. Posterior patch narrow with anterior and posterior margins convex and with a large dark mark in the centre. A row of hairs runs transversely along this patch. The remaining pair of sclerites are lateral patches, one in each pleural region. They are hairy and each bears a dark mark in the region nearest the dorsal surface. *Legs :* approximately equal in size, shortest in front. Femur and tibia hairy, tarsus not so hairy. Tarsal claw long, with a basal spine. *Abdomen :* fairly large stump-like dorsal sucker on first segment, but lateral suckers much reduced. Gills filiform, arranged in circlets near anterior margin of each of segments II to VII. Lateral line weakly developed, formed of fine hairs. Anal claws small, of two segments, but supported by three sclerites black in colour. Three long bristles adjacent to the posterior sclerite.

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LARVAE OF THE BRITISH TRICHOPTERA. 6

By N. E. HICKIN, Ph.D., F.R.E.S.

Silo pallipes Fabricius (SERICOSTOMATIDAE).
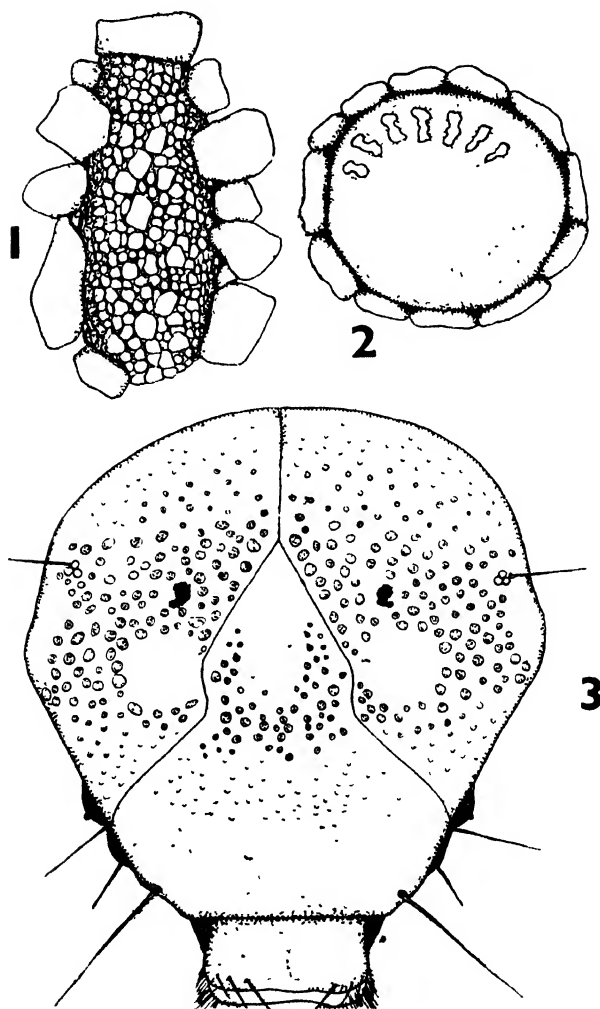
FIGS. 1–3.—*S. pallipes.* 1, case; 2, view of posterior end of pupal case; 3, head.

LARVAE were collected from a small, rapidly flowing stream at the edge of a beechwood at Cranham, Gloucestershire, where they were very plentiful. The stream was bordered with thick vegetation, and the bottom covered with small rocks and stones of limestone. A few larvae were reared to maturity.
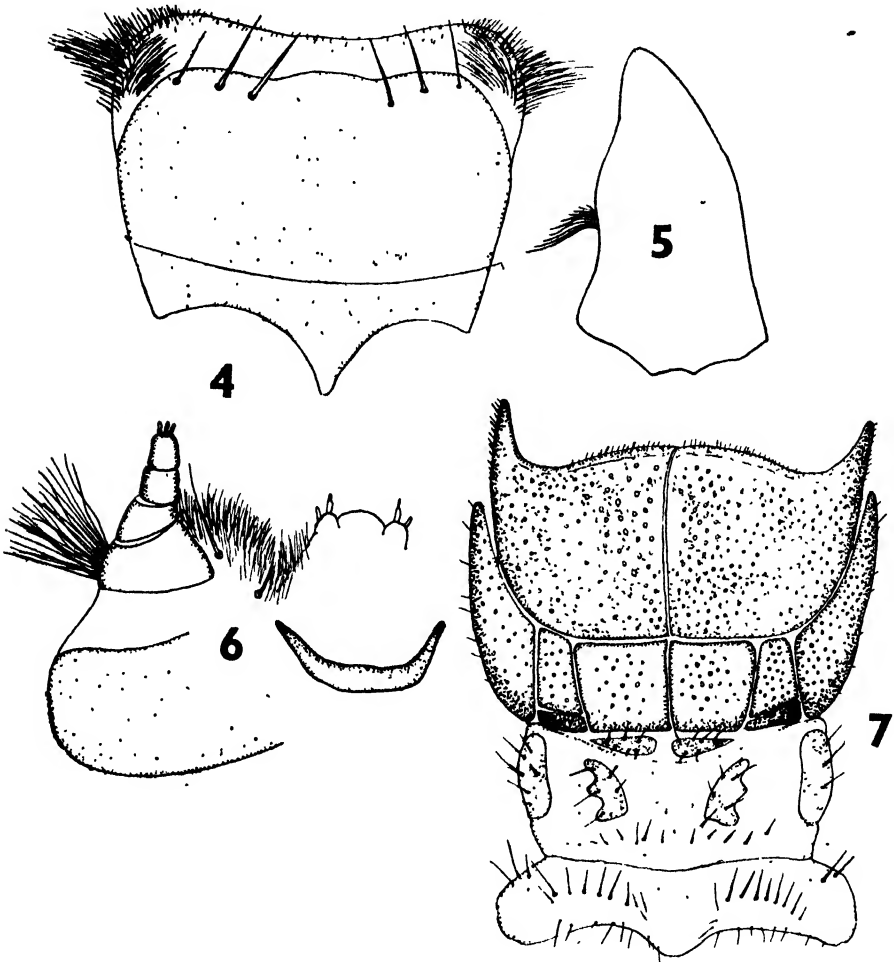
FIGS. 4–7.—*S. pallipes.* 4, labrum; 5, mandible; 6, maxilla and labium; 7, thorax and first abdominal segment.

Case. A tubular portion of sand grains with small pebbles cemented along two sides giving dorsal and ventral surfaces to the case, ventral surface slightly flattened. Length 8 mm., breadth 4·5 mm. Shortly before pupation the anterior end is closed with a small stone, whilst at the posterior end the opening is filled with a dark brown secretion with the exception of a small lattice of about seven small slits arranged in an arc. *Larva :* eruciform, cylindrical with abdomen gradually tapering distally. Sclerotised parts uniformly dark brown. Pro- and mesothoracic nota sclerotised, forming a globular structure distinct

from the partially sclerotised metathoracic notum. *Head :* hypognathous, ovoid, tapering towards oral end. Angles on genae fairly sharp. Eyes small, set close together at front of head. Clypeus wide at the base. Antennae very much reduced. Head covered with small dark tubercles, except a small area at aboral end of clypeus and an area on each gena adjacent to this. The size of the tubercles decreases towards the top of the head, on the frons, and on the clypeus towards the labrum. Very few bristles present, one large pair at the base of the clypeus and three smaller pairs. One pair of the latter are lateral to the eyes and the other two pairs are lateral to the base of the clypeus. *Mouth-parts :* labrum of two parts, a proximal sclerotised part, with a median prolongation at the base and bearing three pairs of bristles transversely near the anterior margin, and a distal unsclerotised part having a brush of fine hairs on each side. Mandibles acute, with a bunch of fine hairs at about the middle of the inner edge a little nearer the base. Maxillary palps four-segmented with basal segments bulbous and brush of fine hairs emerging from the basal segment. Galea covered with fine hairs and bearing two bristles. Labium with fine hairs at the side, labial palps two-segmented with a tubercle on each segment. Bow-shaped sclerite at base of labium. *Thorax :* pro- and mesothoracic nota sclerotised, covered with small dark coloured tubercles. Pronotum dark reddish-brown with three light patches, one median, two lateral. Pronotum with median suture, convex, anterior margin fringed with small hairs. Pro- and mesonota have lateral wing-like extensions extending anteriorly.
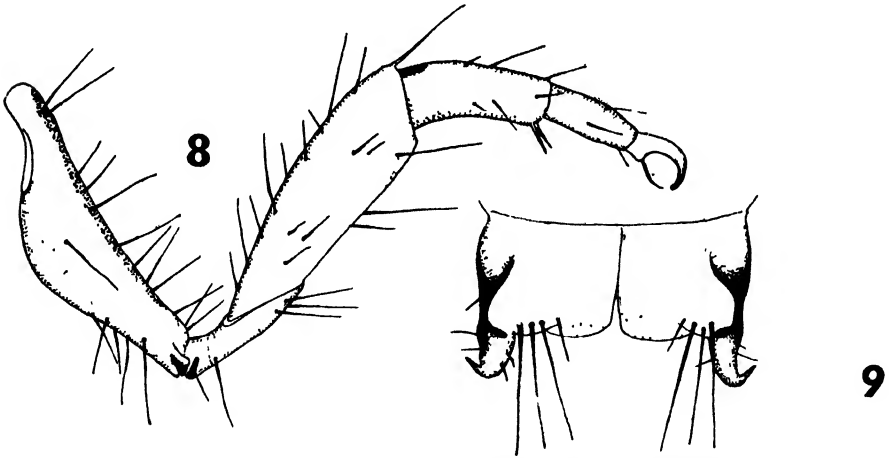
FIGS. 8–9.—*S. pallipes.* 8, prothoracic leg; 9, anal claws.

Mesonotum lighter in colour than pronotum, divided into ten parts, by a median suture, two lateral longitudinal sutures and two transverse sutures on each side. The hinder of the outer pair of sclerites is not visible from the dorsal surface. Metanotum with six sclerotised patches; two small pear-shaped patches lie transversely near the mesonotum, with a pair of slightly larger patches lying posteriorly with sinuate margins. The largest patches occupy a position in the pleural region. All six sclerotised patches bear bristles. *Legs :* equal, tarsal claws strongly curved and with a basal spine. Anterior edge of femur with continuous dark mark. Prosternal horn present. *Abdomen :* first segment bulbous laterally and in centre of posterior margin. Branched gills present on the second to seventh segments inclusive. Lateral line reaching to the beginning of the eighth segment. Anal claws supported by single large sclerites having small extension pointing towards and almost meeting one small and three large bristles.

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BOOK NOTICE.

Insects and their stories. By H. HOOGSTRAAL. Obl. 8vo. New York. (Thomas Y. Crowell), 1941. pp. [viii] + 144, 98 figs. Price $2.

The object of this book is to arouse a general interest in common insects which might be encountered by any person in America. Some 46 insects are described in general terms and an enlarged illustration is given of each with, in addition, a detail of some interesting part of the insect. The text, which is written in non-technical language, is intended ". . . to follow the career of each of these insects : where and how it breeds, what it eats, how long it lives and where, and what its importance is in our human world." The book is printed by offset process and the text is in double column.

DIFFERENCES IN RESISTANCE TO TOXIC SUBSTANCES SHOWN BY DIFFERENT BODY COLOUR MUTANTS IN *DROSOPHILA* (DIPTERA)

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INTRODUCTION.

THE darkening of a dipteron's cuticle is due to a tanning process caused by polyphenols (Fraenkel and Rudall, 1940, Pryor 1940), resulting at the same time in its hardening and dehydration. One would expect this harder and darker cuticle to be less permeable to water than a light one. On this assumption, experiments were undertaken (Kalmus, 1941) to demonstrate that the lighter mutants of four *Drosophila* species die earlier and lose weight more rapidly than their wild type sibs, when starving in a dry atmosphere.

Differences in permeability of cuticles of various coloration need not be confined to water. In this paper it will be shown that the structural changes in the cuticle accompanying darkening decrease the permeability not only for various water-soluble substances, but also for mineral oils and oil-soluble substances. Inherited differences in resistance to toxic substances can provide the raw material for selection. Therefore the bearing of the results on problems of chemical selection, and in particular on industrial melanism, are briefly discussed.

MATERIAL.

The following stocks of *Drosophila melanogaster* and *D. pseudoobscura*, race A, were used in the experiments.

D. melanogaster :	oregon +,	wild type (+)
	yellow³⁹ᶜ,	a lighter mutant (*y*)
	black,	a dark mutant (*b*)
	ebony,	a dark mutant (*e*)
D. pseudoobscura :	wild type (+)	
	yellow,	a light mutant (*y*)

The mutants may be briefly described. The recessive gene yellow causes the absence of all black elements from the colour pattern of both species. As the wild type of *D. melanogaster* is yellow-brown with black stripes, the difference in appearance is not very striking, but in *pseudoobscura*, in which the wild type is dark, it is very conspicuous. The semi-dominant gene black in *D. melanogaster* increases the extent and intensity of a dark colour pattern on the thorax and other parts of the body and in the homozygous form causes a dark cloudy area on the wings, following the venation. The semi-dominant ebony causes a similar wing effect and a more general darkening of the whole body.

Crosses were cultured on the usual agar-maize-yeast medium, *D. melanogaster* directly in bottles, *D. pseudoobscura* being mated in tubes and transferred to bottles after one week.

Sibs differing only in one of the alleles in a chromosome which determines the cuticle colour were always obtained in the second generation. The procedure for y, which is sex-linked in both species, was as follows :—

$$p = \frac{y}{y} \, \female \times y^+ \, \male$$

$$F_1 = \frac{y}{y^+} \, \female \times y \, \male$$

$$F_2 = \frac{y}{y^+} \, \female, \frac{y}{y} \, \female, y^+ \, \male, y \, \male$$

Phenotypically half the females and half the males in the F_2 generation were wild type, the others being yellow.

The procedure for the autosomal gene b (and similarly e) was slightly different :—

$$p : \frac{b}{b} \, \female \times \frac{b^+}{b^+} \, \male$$

$$F_1 : \frac{b^+}{b} \, \female \times \frac{b^+}{b} \, \male$$

$$F_2 : \frac{b^+}{b^+} \, \female, \frac{b^+}{b} \, \female, \frac{b}{b} \, \female, \frac{b^+}{b^+} \, \male, \frac{b^+}{b} \, \male, \frac{b}{b} \, \male$$

The separation of the homozygous mutant quarter of F_2 from the rest is always easy for b and e, but, because they are semi-dominant, complete separation of the heterozygous half from the homozygous wild type (1 quarter) is impossible. It is therefore difficult to determine the differences of all three groups, and consequently a comparison was made between the homozygous mutants and the lightest individuals of the rest. It is quite possible that the inclusion of some heterozygotes in the experiments has decreased the difference in reactions observed.

For the experiments flies of known, and fairly uniform, age were used by collecting those which emerged during a specific period (1–2 days) from one or several bottles. They were then kept for several days in a bottle on fresh food.

TECHNIQUE.

For the experiments, groups of forty flies (ten each of wild type males, wild type females, mutant males and mutant females) were put in tubes stoppered with cotton wool. They were narcotised with CO_2 from a Kipp apparatus. Immobilisation was quickly attained, and lasted for 1–3 minutes. Directly after narcotisation the insects were placed in petri dishes 9 cm. in diameter and sprayed. The bottom of each petri dish was covered with tricoline, a textile material, to absorb excess spray fluid.

The chemicals were applied by means of an apparatus designed to administer controlled and uniform deposits of contact insecticides (Potter 1941). Major variations in deposit were obtained by varying the amount of fluid in the reservoir of the atomiser, and small corrections made by adjusting the pressure of the compressed air working the atomiser. The amount of the deposit of each of the fluids tested was controlled by weighings.

After spraying, the petri dishes were covered with muslin and kept in the

laboratory at temperatures of 18–20° C. and relative humidity 60–75%. The following substances were tested :—

(1) *Heavy mineral oil.* Specific gravity 0·880, viscosity Redwood I at 21° C. 104″, closed flash point 154° C., boiling range 10% at 298–319° C., 80% at 319–388° C., unsulphonated residue by volume 88%.

(2) *Light oil (kerosene).* Specific gravity 0·795, closed flash point 46° C., initial boiling point 160° C., final boiling point 290° C., 35% distilling to 200° C.

(3) *Coal tar oil (creosote oil).* Specific gravity 1·029, tar acids 16·5%, boiling range 20% at 220° C., 80% at 297° C. Applied as a 0·8% emulsion in water.

(4) *Pyrethrum extract.* Kenya flowers admixed with decolorising charcoal were extracted with petroleum ether to give an almost colourless solution. The petroleum ether was removed, the resin taken up with acetone, and diluted with 0·1% sulphonated lorol to give a final spray solution containing 0·5 mg. of pyrethrin I and 10 ml. of acetone per 100 ml.

(5) *Sulphuric acid A.R. in water.*

The following criteria were used to assess the effect of the toxic substances :—
(1) survival; (2) loss of weight; (3) conspicuous collapse of the eyes.

SURVIVAL.

After treatment the flies were examined and placed in the categories, normal, moribund (*i.e.*, those only capable of moving their appendages), and those apparently dead. Differences in mortality between the wild type flies and the mutants were found after spraying with all the substances tested. The yellow mutants of both species showed a higher percentage mortality after a given time than the wild types. The dark mutants black and ebony in *D. melanogaster* survived longer than the wild type after treatment with heavy oil, but the difference between ebony and wild type was not significant. The mutant black survived longer than wild type after treatment with sulphuric acid. The results are given in Table 1.

TABLE 1.

Survival after spraying.

Treatment and species	Genetical constitution. sex and phenotype (5)			No. of replicates	Hours after spraying	Alive	Moribund	Dead	Alive in controls
1. Heavy mineral oil (1)	y^+	♂	w.t.	4	6	33	2	5	40
0·6 mg./cm.²	y	♂	l.			5	12	23	40
D. pseudoobscura race A	$\frac{y^+}{y}$	♀	w.t.			39	1	0	40
	$\frac{y}{y}$	♀	l.			7	11	22	40
2. Heavy mineral oil (1)	y^+	♂	w.t.	2	6	13	5	2	20
0·6 mg./cm.²	y	♂	l.			0	7	13	20
D. melanogaster or	$\frac{y^+}{y}$	♀	w.t.			10	6	4	20
	$\frac{y}{y}$	♀	l.			0	11	9	20
3. Heavy mineral oil (1) 0·3 mg./cm.²	$\frac{b^+}{b^+}$	♂	w.t.	3	18	4	3	23	30

TABLE 1 (*continued*).

Treatment and species	Genetical constitution, sex and phenotype (5)			No. of repli-cates	Hours after spray-ing	Alive	Mori-bund	Dead	Alive in con-trols
D. melanogaster or	$\frac{b}{b}$	♂	d.			12	4	14	30
	$\frac{b^+}{b^+}$	♀	w.t.			11	1	18	30
	$\frac{b}{b}$	♀	d.			17	1	12	30
4. Heavy mineral oil (1) approx. 0·2 mg./cm.²	$\frac{e^+}{e^+}$	♂	w.t.	3	22	12	1	8	—
D. melanogaster or	$\frac{e}{e}$	♂	d.			14	0	7	—
	$\frac{e^+}{e^+}$	♀	w.t.			21	0	1	—
	$\frac{e^+}{e^+}$	♀	d.			22	0	0	—
5. Kerosene (2) 0·2 mg./cm.²	y^+	♂	w.t.	3	0·5	9	17	4	30
D. pseudoobscura race A	y	♂	l.			0	20	10	30
	$\frac{y^+}{y}$	♀	w.t.			14	13	3	30
	$\frac{y}{y}$	♀	l.			4	20	6	30
6. Coal-tar oil (3) emul-sion 5 mg./cm.³	y^+	♂	w.t.	3	6	7	22	1	30
D. pseudoobscura	y	♂	l.			2	19	9	30
	$\frac{y^+}{y}$	♀	w.t.			12	17	1	30
	$\frac{y}{y}$	♀	l.			5	16	9	30
7. Pyrethrum extract (4) 7 mg./cm.²	y^+	♂	w.t.	3	19	11	14	5	29
D. pseudoobscura race A	y	♂	l.			5	16	9	25
	$\frac{y^+}{y}$	♀	w.t.			17	8	5	30
	$\frac{y}{y}$	♀	l.			8	16	9	29
8. Sulphuric acid (5) (0·01%) 5 mg./cm.²	y^+	♂	w.t.	3	28	16	4	10	20
D. pseudoobscura race A	y	♂	l.			3	3	24	19
	$\frac{y^+}{y}$	♀	w.t.			18	3	9	23
	$\frac{y}{y}$	♀	l.			12	6	12	20
9. Sulphuric acid (5) (0·005%) 5 mg./cm.²	$\frac{b^+}{b^+}$	♂	w.t.	3	28	8	3	19	—
D. melanogaster or	$\frac{b}{b}$	♂	d.			22	2	6	—
	$\frac{b^+}{b^+}$	♀	w.t.			20	3	7	—
	$\frac{b}{b}$	♀	d.			26	2	2	—

WEIGHING.

A differential loss of weight, presumably mainly water, of the dark and light specimens of four *Drosophila* species has previously been described (Kalmus 1941). A similar difference was established in these experiments after spraying with heavy or light oil. The loss of weight after spraying with the heavy oil was much quicker than in untreated controls and was even more rapid after treatment with the more volatile oil (Table 2). The technique used was the

same as in the survival experiments, but fewer individuals were treated. Weighings were made on a torsion balance of capacity 5 and sensitivity 0·01 mg.

TABLE 2.

Loss of weight of *D. pseudoobscura* race A.

Treatment	Genetical constitution, sex and phenotype	No. of individuals	Original weight mg.	No. dead after 2 hours	Average weight of all flies after 2 hours mg.	% of original weight	No. dead after 17 hours	Average weight of all flies after 17 hours mg.	% of original weight
Heavy mineral oil 0·3–0·4 mg./cm.²	y^+ ♂ w.t.	8	1·01 ± 0·02	0	0·82 ± 0·03	82	2	0·74 ± 0·02	74
	y ♂ l.	8	0·84 ± 0·03	1	0·65 ± 0·01	77	6	0·49 ± 0·02	58
	$\frac{y^+}{y}$ ♀ w.t.	8	1·13 ± 0·03	0	1·03 ± 0·06	91	0	0·90 ± 0·06	79
	$\frac{y}{y}$ ♀ l.	8	1·16 ± 0·07	1	1·00 ± 0·07	86	8	0·67 ± 0·07	58
Kerosene 0·2 mg./cm.²	y^+ ♂ w.t.	7	0·93 ± 0·06	3	0·75 ± 0·06	81	5	0·62 ± 0·06	66
	y ♂ l.	8	0·82 ± 0·03	8	0·57 ± 0·02	70	8	0·38 ± 0·01	46
	$\frac{y^+}{y}$ ♀ w.t.	8	1·11 ± 0·06	0	0·87 ± 0·06	79	2	0·82 ± 0·05	74
	$\frac{y}{y}$ ♀ l.	8	1·17 ± 0·06	4	0·94 ± 0·04	72	8	0·60 ± 0·04	51

COLLAPSE OF EYES.

After treatment of the flies with the more volatile mineral oil a curious effect was observed on the eyes after death. One or both eyes were collapsed, *i.e.*, their convex surface had become dented. The frequency of this occurrence was significantly greater in the yellow mutants of *D. pseudoobscura* than in the wild type (Table 3).

TABLE 3.

Collapse of eyes of offspring from a crossing of $\frac{y^+}{y} \times y$ in *D. pseudoobscura* race A.

Treatment	Genetical constitution, sex and phenotype			No. of individuals	No. alive	One eye collapsed	Both eyes collapsed
Kerosene 0·2 mg./cm.²	y^+	♂	w.t.	30	0	2	16
Examination after 17 hours	y	♂	l.	30	0	2	26
	$\frac{y^+}{y}$	♀	w.t.	30	2	2	10
	$\frac{y}{y}$	♀	l.	30	0	1	22

No collapse of eyes was observed after treatment with any of the other substances tested. Two factors are probably involved in this phenomenon. (*a*) the differential rate of desiccation, which diminished the body turgor and (*b*) a difference in the mechanical strength of the cornea and its softening by the light oil.

DISCUSSION.

It is not at present clear whether the differences in reaction of the mutants to all the chemicals used are due to a common cause. There may be a sequence of unknown factors resulting in a differential " general resistance " to the toxic substances which in the species tested is correlated with the cuticle colour. However, it is simplest to assume that a dark cuticle is less permeable to the substances tested than a lighter one. As the decrease in permeability of the darker forms applies to water and oil as well as to substances soluble in either of these agents, it is probably not due to the observed dehydration during darkening but to the formation of a firmer and stabler cuticular structure.

Dark and light mutants occur in many insect species. They are usually controlled by one or two genes. The following generalisations may therefore be of some heuristic value : greater protection against toxic substances conferred by a dark cuticle may become a selective advantage under various conditions, of which I will mention two only.

(1) Chemical selection may favour the survival of the darker members of an insect population that is subjected to treatment with insecticides. Thus a " resistant " race may develop in place of a former " susceptible " one.

(2) It may be the cause of industrial melanism, *i.e.*, the progressive replacements in industrial and urban districts of light individuals of many insect species, mainly Lepidoptera, by darker mutants. There is some indication that industry may affect the coloration of *Drosophila*. The analysis of Caucasian wild populations of *D. melanogaster* by Dubinin (1934) showed that the mutant gene ebony, which causes dark body colour and was also used in the present experiments, is present only in the neighbourhood of Batum, an industrial district, where 79% of the chromosomes tested carried it.

The dark colour of melanic Lepidoptera is principally localised in the scales and not in the cuticle proper. Therefore it might give less selective advantage. However, a very slight advantage carried by rather frequent single genes will spread at a rate comparable with those observed (Haldane 1924–32, Fisher 1930, Wright 1930). Up to the present only a few data published by Ford (1940) indicate that melanic offspring of starved families of the moth *Boarmia repandata* are hardier, *i.e.*, that they survive longer than the lighter sibs. Furthermore, Hovanitz (1941) found correlations between Lepidopteran coloration and climatic factors, such as temperature and humidity, which support the view that permeability for water at least is correlated with the colour of the scales. Unfortunately I am not able at present to work on Lepidoptera showing industrial melanism.

SUMMARY.

(1) The light mutant yellow in *Drosophila melanogaster* and *D. pseudoobscura*, race A, was less resistant than the darker wild type to spraying with heavy or light petroleum oils, a tar-oil emulsion in water, a pyrethrum extract and weak solutions of sulphuric acid. The dark mutant black in *D. melanogaster* showed a significantly greater survival than the wild type after spraying with heavy oil and sulphuric acid; the dark mutant ebony showed no significant differences.

(2) The yellow mutant of *D. pseudoobscura*, race A, lost significantly more weight after spraying with light and heavy oil than the wild type.

(3) A collapse of the eyes of the dead flies was noticed after treatment with the light oil. This was significantly more frequent in the yellow mutant of *D. pseudoobscura* than in the wild type.

(4) It is probable that the differences in reaction between individuals of different body colour may be due to differences in the permeability of the cuticles to the substances tested.

(5) The resistance of darker forms may become an advantage if insecticides of the type used are applied to an insect population and may thus cause the formation of a darker "resistant" population. This mechanism may also perhaps explain industrial melanism.

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LARVAE OF THE BRITISH TRICHOPTERA. 7

By N. E. Hickin, Ph.D., F.R.E.S.

Phryganea grandis L. (PHRYGANEIDAE).

THE larva of this species is very large and is commonly met with in ponds, lakes and slow-moving rivers. The specimens from which the following description is made were collected from Kings Heath, Birmingham, and compared with larvae taken from Clay Pond, Wray, Windermere.

Case. 30–50 mm. long and 8–9 mm. wide. Made of fragments of leaves uniformly cut, arranged in a spiral whorl and tapering down to the distal end. When dragging its case along, the larva makes spasmodic jerking movements with the prothoracic legs
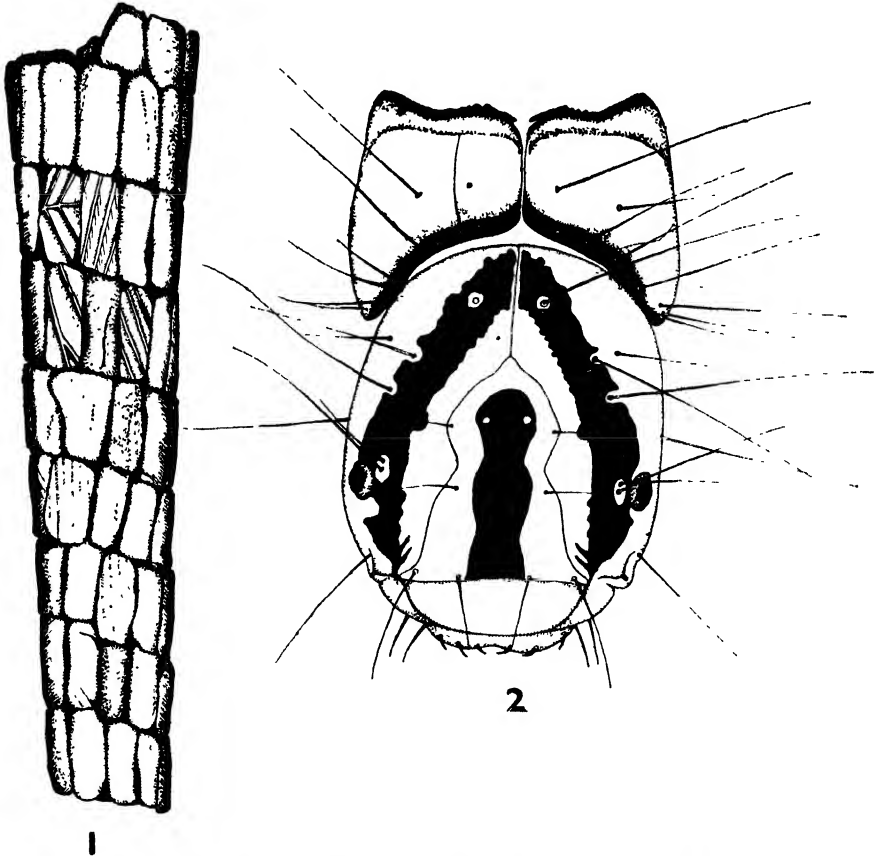
FIGS. 1–2.—*P. grandis.* 1, case; 2, head and prothorax.

Larva : eruciform. The head is hypognathous and only the prothorax is sclerotised. With the exception of the legs the rest of the body is white. Length 30–40 mm., width 4–5 mm. *Head :* the head is bright yellow with two dark bands running over it from the anterior margin of the genae to cervical region of the frons, where they meet. These dark bands skirt the clypeus and appear as an inverted " V ". A single dark band runs down the median line of the clypeus. Within the " V "-shaped band, two large bristles emerge from a yellow patch near the eye on each side. A pair of single bristles also emerges from this band posterior to the eyes. *Mouth-parts :* the labrum has the median part of the anterior margin concave. Six spines arise from this margin. A pair of spines also occupies a median position, with a spine on each lateral edge. The mandibles are three-toothed and
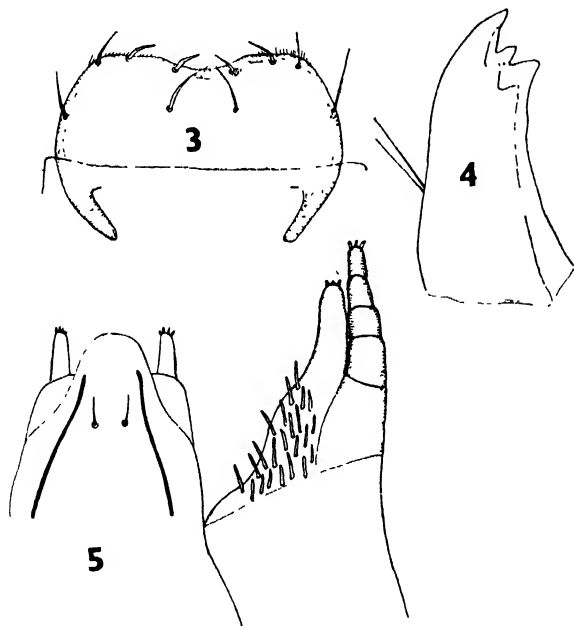
Figs. 3–5.—*P. grandis.* 3, labrum; 4, mandibles; 5, labium and maxilla.

rather long. The left mandible has the teeth doubled. From the base of the maxillae arise a large number of blunt spines. The palp is five-segmented and the mala is palp-like, having a few tubercles at the distal end. The labial palps are distinct and have tubercles on the distal extremities. Two long bow-shaped sclerites are visible within the labium. *Thorax :* only the prothorax is sclerotised. It is bright yellow in colour with a transverse dark band across the anterior margin and another running across the posterior margin. A row of large bristles is set within the anterior band and a second row emerges across the centre of the prothorax transversely. A group of bristles occupies a lateral position on each side of the meso- and metathorax. *Legs :* a prosternal horn is present, *i.e.*, an un-sclerotised finger-like prolongation of the prosternum lying between the femora of the pro-thoracic legs. Prothoracic legs shortest, mesothoracic slightly longer, whilst the meta-thoracic legs are considerably longer. In all legs the ventral margin of tibia and the distal part of the trochanter are edged with bristles between which lie small spines. The latter are also present on the tarsus of the meso- and metathoracic legs. In all legs a spur is

situated at the base of the tarsal claw.   In the metathoracic leg the tarsal claw is very long. On the femur of prothoracic leg are a number of small scales edged with fine hairs.   *Abdomen :* on the first abdominal segment is a large median process which is pointed and directed posteriorly and a pair of blunt lateral processes which curve forwards.   The lateral processes have a circlet of small setae situated at their extremities.   The remainder of the abdominal segments have filamentous gills.   The eighth segment has only a single pair of gills—situated at the anterior pleural region of the segment.   Anal claws with three auxiliary claws.
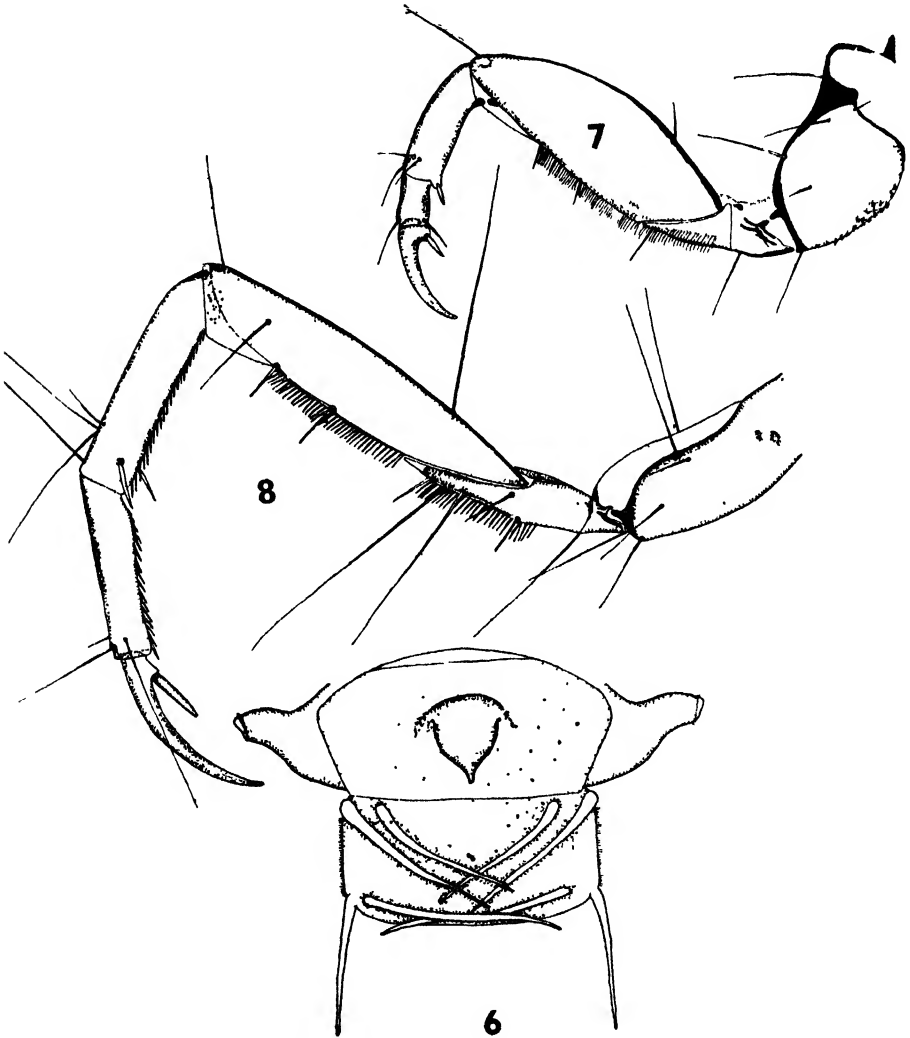
Figs. 6–8.—*P. grandis.*   6, abdominal segments; 7, prothoracic leg; 8, metathoracic leg.
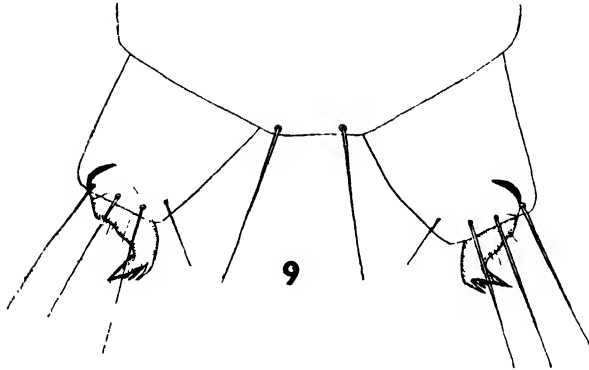
Fig. 9.—*P. grandis.* Anal claws.

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BOOK NOTICE.

Supplement to Insects of North Carolina. By C. S. BRIMLEY. 8vo. Raleigh, North Carolina. (North Carolina Department of Agriculture.) 1942. pp. 1–39.

In August, 1938, the *Insects of North Carolina* was published by the North Carolina Department of Agriculture, and since that time a number of species has been added and a few corrections made to the list. The present supplement brings the total number of insects recorded for North Carolina to 10,401, of which the chief are 3080 Coleoptera, 1970 Diptera, 1840 Hymenoptera, 1245 Lepidoptera, 659 Homoptera, and 516 Hemiptera.

Book Notice.

I. The classification of the genus *Drosophila*, with descriptions of nine new species. By A. H. STURTEVANT.

II. New species in the *quinaria* group of the subgenus *Drosophila*. By Warren P. SPENCER.

III. Description of new species of the subgenera *Hirtodrosophila* and *Drosophila*. By J. T. PATTERSON and Marshall R. WHEELER.

8vo. Austin, Texas, U.S.A. (University of Texas Publication No. **4213**). 1942. pp. 1–109.

The papers included in this publicatiera are indicated by their titles. The first is an attempt to bring up to date work on the classification of *Drosophila*, but is not regarded as a final revision of that genus, since it is thought that a number of species remains undiscovered in the Nearctic region. The paper includes the description of nine new species, and is completed by a key to the North American species of the genus.

The second paper contains a description of six new species of *Drosophila* related to the *quinaria* group.

The third paper contains the description of thirty species in the subgenera *Hirtodrosophila* and *Drosophila*.

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